Gross Infestations of the Domestic Rat with Ectoparasites ..... Neal M. Randolph and R. B. Eads 538
Benyene Hexachloride for Animal Parasites ..... Raymond Roberts 539
Comparative Toxicity to Insects of Benzene Hexachloride and DDT ..... G. T. Bottger and Clemence Levin 539
DDT Used in Control of Latrine Flies ..... Deane P. Furman 541
Rearing Oriental Fruit Moths and Parasites from Infested Peach Terminals ..... Norris D. Blackburn 542
The Abundance and Control of Flies on a College Campus ..... F. R. Shaw and A. I. Bourne 543
A Laboratory Method of Flea Culture ..... J. P. Linduska and J. H. Cochran 544
A New Lacebug in Florida ..... N. Stahler 545
DDT for Control of the Biting Sheep Louse ..... H. E. Parish and C. A. Rude 546
Lizards Feeding on Ants in Utah ..... George F. Knowlton and William P. Nye 546
Birds Feeding on Ants in Utah ..... George F. Knowlton, R. S. Roberts and S. L. Wood 547
Toxicity of some N-Substituted Phthalimides to Codling Moth Larvae ..... E. H. Siegler and S. I. Gertler 549
Control of Aphids on Spinach with Hexachlorocyclohexane ..... Dwight Isely and Floyd D. Miner 550
Insects in Shelled Peanuts in Relation to Storage and Bagging ..... Theodore L. Bissel and Minter DuPree 550
Editorial 553
Obituary 554
Entomologists' Meetings 556

American Association of Economic Entomologists to hold Annual Meetings in Pittsburgh Dec. 9 to 12, 1946

The annual meeting of the American Association of Economic Entomologists will be held December 9 to 12 inclusive in the Hotel William Penn, Pittsburgh, Pennsylvania. The Hotel has set aside a generous number of rooms for those in attendance and early application for reservations should be made.

This will be a joint meeting with the Entomological Society of America. The Program Committee, acting for both societies, consists of A. M. Boyce, Chairman, G. J. Haeussler and C. E. Palm. The committee is integrating the schedule so that there will be several joint sessions and a maximum opportunity for the members of both societies to enjoy the contacts and the two programs.—E.N.C.

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 39 August, 1946 No. 4

Common Names of Insects Approved by the American Association of Economic Entomologists[1]

C. F. W. MUESEBECK, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

This list contains all common names approved to date by the American Association of Economic Entomologists for specific insects. The few approved common names applicable not to definite species but to groups of species or families are withheld for inclusion in a separate list to be developed in accordance with instructions to the Committee on Common Names voted at the annual meeting held at Dallas, Texas, in December 1945.[2]

Acting under authorization given at the Dallas meeting,[3] the Committee has made numerous editorial changes in approved names in the interest of uniformity of formation. Recommendations published in 1923[4] and 1942,[5] which have had wide support, have been accepted as general guides by the Committee in editing the approved names. One principle adopted, the application of which is responsible for most of the changes made, was well stated by Metcalf in the 1942 paper just cited: "When the substantive part of a name is correctly applied, as *fly* for Diptera, . . . , *worm* for Annelida, *louse* for Anoplura or Mallophaga, *moth* for Lepidoptera, *flea* for Siphonaptera, and the like, the distinguishing part of the common name shall stand as an adjective—a separate word. But when these substantives are used in an entirely false, arbitrary and misleading sense," the substantive is to be combined with its modifying name (whitefly, sowbug, earworm, sawfly, billbug, antlion, etc.), except where the combined word would be excessively long or awkward, in which case the hyphen is to be used. The Committee has restricted its editing to technical corrections required by the application of such principles. It has not altered other names which now seem inappropriate or otherwise unsatisfactory. Changes of that type, the Committee believes should only be effected through the normal procedure involving balloting by the Association membership.

The list here given supersedes and voids all previous lists of approved common names published by the Association. Taxonomists of the Division of Insect Identification, United States Bureau of Entomology and Plant Quarantine have checked all scientific names except those in a few restricted groups on which outside specialists have been consulted; and the scientific names shown are those stated to be in current use.

COMMON NAMES OF INSECTS

I. INSECTS LISTED BY COMMON NAMES

achemon sphinx.....*Pholus achemon* (Drury)
ailanthus webworm.....*Atteva aurea* (Fitch)
Alaska spruce beetle...*Dendroctonus borealis* Hopk.
alder bark beetle.....*Alniphagus aspericollis* (Lec.)
alder flea beetle.....*Altica ambiens* (Lec.)
alfalfa caterpillar...*Colias philodice eurytheme* Bdvl.
alfalfa gall midge *Asphondylia websteri* Felt
alfalfa looper.....*Autographa californica* (Speyer)
alfalfa plant bug....*Adelphocoris lineolatus* (Goeze)
alfalfa snout beetle.....*Brachyrhinus ligustici* (L.)
alfalfa webworm.....*Loxostege commixtalis* (Wlkr.)
alfalfa weevil.....*Hypera postica* (Gyll.)

[1] Edited and approved by the Committee on Common Names of Insects, American Association of Economic Entomologists. List prepared for publication by C. F. W. Muesebeck, Chairman.

[2] JOUR. ECON. ENT. 39: 105, 1946.

[3] JOUR. ECON. ENT. 39: 104, 1946.

[4] Report of the Committee on Nomenclature. JOUR. ECON. ENT. 16: 21–4.

[5] Metcalf, C. L. JOUR. ECON. ENT. 35: 795–7

Allegheny mound ant...*Formica exsectoides* Forel
Allegheny spruce beetle.....
Dendroctonus punctatus Lec.
almond moth.....*Ephestia cautella* (Wlkr.)
American cockroach....*Periplaneta americana* (L.)
American dagger moth *Acronycta americana* Harr.
American dog tick *Dermacentor variabilis* (Say)
American grasshopper.....
.....*Schistocerca americana* (Drury)
American plum borer.....
.....*Euzophera semifuneralis* (Wlkr.)
Angoumois grain moth...*Sitotroga cerealella* (Oliv.)
angular-winged katydid.....
.....*Microcentrum retinerve* (Burm.)
apple and thorn skeletonizer.....
.....*Anthophila pariana* (Clerck)
apple aphid.....*Aphis pomi* Deg.
apple bark miner.....*Marmara elotella* (Busck)
apple curculio....*Tachypterellus quadrigibbus* (Say)
apple flea weevil.....*Rhynchaenus pallicornis* (Say)
apple fruit miner.....*Marmara pomonella* Busck
apple fruit moth.....*Argyresthia conjugella* Zell.
apple grain aphid.....
.....*Rhopalosiphum prunifoliae* (Fitch)
apple leaf skeletonizer..*Psorosina hammondi* (Riley)
apple leaf trumpet miner.....
.....*Tischeria malifoliella* Clem.
apple leafhopper.....*Empoasca maligna* (Walsh)
apple maggot.....*Rhagoletis pomonella* (Walsh)
apple red bug.....*Lygidea mendax* Reut.
apple rust mite.....*Vasates schlechtendali* (Nal.)
apple seed chalcid .....*Torymus druparum* Boh.
apple sucker.....*Psylla mali* (Schmdb.)
apple twig beetle...*Hypothenemus hispidulus* (Lec.)
apple twig borer.....*Amphicerus hamatus* (F.)
arborvitae leaf miner...*Argyresthia thuiella* (Pack.)
Argentine ant.....*Iridomyrmex humilis* Mayr
argus tortoise beetle.....*Chelymorpha cassidea* (F.)
Arizona cotton stainer..*Dysdercus mimulus* Hussey
Arizona pine beetle..*Dendroctonus arizonicus* Hopk.
army cutworm.....*Chorizagrotis auxiliaris* (Grote)
armyworm.....*Cirphis unipuncta*(Haw.)
artichoke plume moth.....
.....*Platyptilia carduidactyla* (Riley)
ash borer.....*Podosesia syringae fraxini* (Lug.)
ash-gray blister beetle.....*Epicauta fabricii* (Lec.)
ash plant bug.....*Neoborus amoenus* (Reut.)
Asiatic garden beetle...*Autoserica castanea* (Arrow)
Asiatic rice borer.....*Chilo simplex* (Butl.)
asparagus beetle.....*Crioceris asparagi* (L.)
asparagus miner...*Melanagromyza simplex* (Loew)
aspen leaf beetle.....*Chrysomela tremulae* F.
Australian cockroach..*Periplaneta australasiae* (F.)
Australian-pine borer.....
.....*Chrysobothris tranquebarica* (Gmel.)
avocado red mite..*Paratetranychus yothersi* (McG.)
avocado whitefly.....
.....*Trialeurodes floridensis* (Quaint.)
azalea bark scale.....*Eriococcus azaleae* Comst.
azalea lace bug.....*Stephanitis pyrioides* Scott
azalea leaf miner.....*Gracilaria azaleella* Brants
azalea whitefly.....*Aleyrodes azaleae* B. & M.

bagworm....*Thyridopteryx ephemeraeformis* (Haw.)
bald-faced hornet.....*Vespula maculata* (L.)
balsam-fir sawfly.....*Neodiprion abietis* (Harr.)
balsam-fir sawyer..*Monochamus marmorator* (Kby.)
balsam twig aphid.....*Mindarus abietinus* Koch
banana root borer...*Cosmopolites sordidus* (Germ.)
banded cucumber beetle....*Diabrotica balteata* Lec.
banded greenhouse thrips.....
.....*Hercinothrips femoralis* (Reut.)
banded hickory borer.....*Chion cinctus* (Drury)
banded woollybear.....*Isia isabella* (A. & S.)
barnacle scale....*Ceroplastes cirripediformis* Comst.
basswood lace bug.....*Gargaphia tiliae* (Walsh)
basswood leaf roller....*Pantographa limata* G. & R.
bean aphid.....*Aphis fabae* Scop.
bean leaf beetle.....*Cerotoma trifurcata* (Forst.)
bean leaf roller.....*Urbanus proteus* (L.)
bean leaf skeletonizer....*Autoplusia egena* (Guen.)
bean thrips.....*Hercothrips fasciatus* (Perg.)
bean weevil.....*Acanthoscelides obtectus* (Say)
bed bug.....*Cimex lectularius* L.
beech blight aphid...*Prociphilus imbricator* (Fitch)
beech scale.....*Cryptococcus fagi* (Baer.)
beet armyworm.....*Laphygma exigua* (Hbn.)
beet leaf beetle.....*Erynephala puncticollis* (Say)
beet leafhopper.....*Eutettix tenellus* (Baker)
beet webworm.....*Loxostege sticticalis* (L.)
bella moth.....*Utetheisa bella* (L.)
bertha armyworm.....*Barathra configurata* (Wlkr.)
bidens borer.....*Epiblema otiosana* (Clem.)
birch casebearer.....*Coleophora salmani* Heinr.
birch leaf miner.....*Fenusa pusilla* (Klug)
birch skeletonizer.....
.....*Bucculatrix canadensisella* Chamb.
bird tick.....*Haemaphysalis chordeilis* Pack.
black army cutworm.....*Actebia fennica* (Tausch.)
black blister beetle..*Epicauta pennsylvanica* (Deg.)
black blow fly.....*Phormia regina* (Meig.)
black carpenter ant.....
...*Camponotus herculeanus pennsylvanicus* (Deg.)
black carpet beetle.....*Attagenus piceus* (Oliv.)
black cherry aphid.....*Myzus cerasi* (F.)
black cherry fruit fly.....*Rhagoletis fausta* (O. S.)
black citrus aphid.....*Toxoptera aurantii* (Fonsc.)
black cutworm.....*Agrotis ypsilon* (Rott.)
black elm bark weevil.....*Magdalis barbita* (Say)
black grain stem sawfly.....*Cephus tabidus* (F.)
black-headed ash sawfly..*Tethida cordigera* (Beauv.)
black-headed budworm.....*Acleris variana* (Fern.)
black-headed fireworm...*Rhopobota naevana* (Hbn.)
Black Hills beetle...*Dendroctonus ponderosae* Hopk.
black-horned tree cricket.....
.....*Oecanthus nigricornis nigricornis* Wlkr.
black horse fly.....*Tabanus atratus* F.
black lady beetle.....*Rhizobius ventralis* (Er.)
black larder beetle.....*Dermestes ater* Deg.
black-legged tick.....*Ixodes scapularis* Say
black-legged tortoise beetle.....
.....*Jonthonota nigripes* (Oliv.)
black-margined aphid.....*Monellia costalis* (Fitch)
black peach aphid.....
.....*Anuraphis persicae-niger* (Smith)
black pecan aphid.....
.....*Melanocallis caryaefoliae* (Davis)
black pine leaf scale..*Aspidiotus californicus* Clmn.
black scale.....*Saissetia oleae* (Bern.)
black swallowtail.....*Papilio ajax* L.
black thread scale....*Ischnaspis longirostris* (Sign.)
black turpentine beetle.....
.....*Dendroctonus terebrans* (Oliv.)
black vine weevil.....*Brachyrhinus sulcatus* (F.)
black widow spider.....*Latrodectus mactans* (F.)
blackberry leaf mite....*Phyllocoptes gracilis* (Nal.)
bloodsucking conenose..*Triatoma sanguisuga* (Lec.)
blue cactus borer.....*Melitara dentata* (Grote)
blue horntail.....*Sirex juvencus* (L.)
blueberry bud mite.....*Aceria vaccinii* (Keif.)
blueberry maggot....*Rhagoletis pomonella* (Walsh)
bluegrass webworm....*Crambus teterrellus* (Zinck.)
blunt-nosed cranberry leafhopper.....
.....*Ophiola vaccinii* (Van D.)

body louse.....*Pediculus humanus corporis* Deg.
boll weevil.....*Anthonomus grandis* Boh.
bollworm.....*Heliothis armigera* (Hbn.)
booklouse.....*Liposcelis divinatorius* (Müll.)
boxelder aphid.....*Periphyllus negundinis* (Thos.)
boxelder bug.....*Leptocoris trivittatus* (Say)
boxelder leaf roller...*Gracilaria negundella* Chamb.
boxelder twig borer..*Proteoteras willingana* (Kearf.)
boxwood leaf miner.....
.....*Monarthropalpus buxi* Laboulb.
boxwood psyllid.....*Psylla buxi* (L.)
bristly cutworm.....*Lacinipolia renigera* (Steph.)
bristly rose-slug.....*Cladius isomerus* Nort.
broad-horned flour beetle.....
.....*Gnathocerus cornutus* (F.)
broad mite.....*Hemitarsonemus latus* (Banks)
broad-necked root borer..*Prionus laticollis* (Drury)
broad-nosed grain weevil.....
.....*Caulophilus latinasus* (Say)
broad-winged katydid.....
.....*Microcentrum rhombifolium* (Sauss.)
broadbean weevil.....*Bruchus rufimanus* Boh.
bronze apple tree weevil...*Magdalis aenescens* Lec.
bronze birch borer.....*Agrilus anxius* Gory
bronzed cutworm...*Nephelodes emmedonia* (Cram.)
brown-banded roach..*Supella supellectilium* (Serv.)
brown chicken louse.....*Goniodes dissimilis* Nitz.
brown dog tick...*Rhipicephalus sanguineus* (Latr.)
brown-headed ash sawfly.....
.....*Tomostethus multicinctus* (Roh.)
brown salt-marsh mosquito...*Aedes cantator* (Coq.)
brown spider beetle.....*Ptinus hirtellus* Sturm
brown-tail moth.....*Nygmia phaeorrhoea* (Donov.)
Bruce spanworm.....*Operophtera bruceata* (Hulst)
buck moth.....*Hemileuca maia* (Drury)
buffalo treehopper.....*Ceresa bubalus* (F.)
bulb mite.....*Rhizoglyphus echinopus* (F. & R.)
bulb scale mite.....*Tarsonemus laticeps* Halb.
bumble flower beetle.....*Euphoria inda* (L.)
bumelia fruit fly.....*Pseudodacus pallens* (Coq.)

cabbage aphid.....*Brevicoryne brassicae* (L.)
cabbage curculio.....*Ceutorhynchus rapae* Gyll.
cabbage looper.....*Trichoplusia ni* (Hbn.)
cabbage maggot.....*Hylemya brassicae* (Bouché)
cabbage seedpod weevil.....
.....*Ceutorhynchus assimilis* (Payk.)
cabbage seedstalk curculio.....
.....*Ceutorhynchus quadridens* (Panz.)
cabbage webworm.....*Hellula undalis* (F.)
cactus scale.....*Diaspis echinocacti* (Bouché)
cadelle.....*Tenebroides mauritanicus* (L.)
calico scale.....*Lecanium cerasorum* Ckll.
California harvester ant.....
.....*Pogonomyrmex californicus* (Buckl.)
California oakworm..*Phryganidia californica* Pack.
California pear-slug.....
.....*Pristiphora californica* (Marl.)
California prionus.....*Prionus californicus* Mots.
California red scale....*Aonidiella aurantii* (Mask.)
California salt-marsh mosquito.....
.....*Aedes squamiger* (Coq.)
California tent caterpillar.....
.....*Malacosoma californicum* (Pack.)
camellia scale.....*Lepidosaphes camelliae* Hoke
camphor scale.....*Pseudaonidia duplex* (Ckll.)
camphor thrips.....*Liothrips floridensis* (Watson)
caragana plant bug.....*Lopidea dakota* Kngt.
Caribbean pod borer.....*Fundella pellucens* Zell.
carnation maggot.....*Hylemya brunnescens* (Zett.)
carnation tip maggot.....*Hylemya abdena* Hall
Carolina grasshopper.....*Dissosteira carolina* (L.)
Carolina mantis....*Stagmomantis carolina* (Johan.)
carpenter bee.....*Xylocopa virginica* (Drury)
carpenterworm.....*Prionoxystus robiniae*(Peck)
carpet beetle.....*Anthrenus scrophulariae* (L.)
carpet moth.....*Trichophaga tapetzella* (L.)
carrot beetle.....*Ligyrus gibbosus* (Deg.)
carrot rust fly.....*Psila rosae* (F.)
carrot weevil.....*Listronotus oregonensis* (Lec.)
casemaking clothes moth.....*Tinea pellionella* (L.)
cat flea.....*Ctenocephalides felis* (Bouché)
cat follicle mite.....*Demodex cati* Megn.
cat louse.....*Felicola subrostrata* (Nitz.)
catalpa midge.....*Itonida catalpae* (Comst.)
catalpa sphinx.....*Ceratomia catalpae* (Bdvl.)
cattle biting louse.....*Bovicola bovis* (L.)
cattle follicle mite.....*Demodex bovis* Stiles
cattle tick.....*Boophilus annulatus* (Say)
Cayenne tick.....*Amblyomma cajennense* (F.)
cecropia moth.....*Samia cecropia* (L.)
cedar tree borer.....*Semanotus ligneus* (F.)
celery leaf tier.....*Phlyctaenia rubigalis* (Guen.)
celery looper.....*Anagrapha falcifera* (Kby.)
celeryworm.....*Papilio ajax* L.
chaff scale.....*Parlatoria pergandii* Comst.
chain-spotted geometer..*Cingilia catenaria* (Drury)
changa.....*Scapteriscus vicinus* Scudd.
charcoal beetle.....*Melanophila consputa* Lec.
cheese skipper.....*Piophila casei* (L.)
cherry casebearer.....*Coleophora pruniella* Clem.
cherry fruit fly.....*Rhagoletis cingulata* (Loew)
cherry fruit sawfly.....*Hoplocampa cookei* (Clarke)
cherry fruitworm.....*Grapholitha packardi* Zell.
cherry leaf beetle.....*Galerucella cavicollis* (Lec.)
cherry maggot.....*Rhagoletis cingulata* (Loew)
chestnut timberworm..*Melittomma sericeum* (Harr.)
chestnut weevil.....*Curculio auriger* (Casey)
chicken body louse.....
.....*Eomenacanthus stramineus* (Nitz.)
chicken head louse.....
.....*Cuclotogaster heterographus* (Nitz.)
chicken mite.....*Dermanyssus gallinae* (Deg.)
chigger.....*Eutrombicula alfreddugèsi* (Oud.)
chigoe.....*Tunga penetrans* (L.)
chinch bug.....*Blissus leucopterus* (Say)
Chinese mantis.....
.....*Tenodera aridifolia sinensis* Sauss.
Chinese obscure scale....*Parlatoria chinensis* Marl.
chrysanthemum aphid.....
.....*Macrosiphoniella sanborni* (Gill.)
chrysanthemum gall midge.....
.....*Diarthronomyia hypogaea* (Loew)
chrysanthemum lace bug.....
.....*Corythucha marmorata* (Uhl.)
chrysanthemum leaf miner.....
.....*Phytomyza chrysanthemi* (Kowarz)
chrysanthemum thrips....*Thrips nigropilosus* Uzel
cigar casebearer.....*Coleophora fletcherella* Fern.
cigarette beetle.....*Lasioderma serricorne* (F.)
citricola scale.....
..... *Coccus pseudomagnoliarum* (Kuw.)
citrophilus mealybug....*Pseudococcus gahani* Green
citrus blackfly.....*Aleurocanthus woglumi* Ashby
citrus bud mite.....*Aceria sheldoni* (Ewing)
citrus mealybug.....*Pseudococcus citri* (Risso)
citrus red mite.....*Paratetranychus citri* (McG.)
citrus root weevil.. *Pachnaeus litus* (Germar)
citrus rust mite.....*Phyllocoptruta oleivora* (Ashm.)
citrus thrips.....*Scirtothrips citri* (Moult.)
citrus whitefly.....*Dialeurodes citri* (Ashm.)
clay-colored billbug.....*Calendra aequalis* (Gyll.)
Clear Lake gnat.....*Chaoborus astictopus* D. & S.
clear-winged grasshopper.....
.....*Camnula pellucida* (Scudd.)

clouded sulphur ..... *Colias philodice philodice* Latr.
cloudy-winged whitefly ..... *Dialeurodes citrifolii* (Morg.)
clover aphid ..... *Anuraphis bakeri* (Cowen)
clover cutworm ..... *Scotogramma trifolii* (Rott.)
clover hayworm ..... *Hypospygia costalis* (F.)
clover head caterpillar ..... *Grapholitha interstinctana* (Clem.)
clover head weevil ..... *Tychius griseus* Schaeff.
clover leaf midge ..... *Dasyneura trifolii* (Loew)
clover leaf weevil ..... *Hypera punctata* (F.)
clover leafhopper ..... *Aceratagallia sanguinolenta* (Prov.)
clover mite ..... *Bryobia praetiosa* Koch
clover root borer ..... *Hylastinus obscurus* (Marsh.)
clover root curculio ..... *Sitona hispidula* (F.)
clover seed chalcid ..... *Bruchophagus gibbus* (Boh.)
clover seed midge ..... *Dasyneura leguminicola* (Lint.)
clover stem borer ..... *Languria mozardi* Latr.
cluster fly ..... *Pollenia rudis* (F.)
cochineal insect ..... *Dactylopius coccus* Costa
coconut leaf roller ..... *Omiodes blackburni* (Butl.)
coconut mealybug ..... *Pseudococcus nipae* (Mask.)
coconut scale ..... *Aspidiotus destructor* Sign.
codling moth ..... *Carpocapsa pomonella* (L.)
coffee bean weevil ..... *Araecerus fasciculatus* (Deg.)
Colorado pine beetle ..... *Dendroctonus approximatus* Dietz.
Colorado potato beetle ..... *Leptinotarsa decemlineata* (Say)
Columbia Basin wireworm ..... *Limonius subauratus* Lec.
Columbian timber beetle ..... *Corthylus columbianus* Hopk.
columbine borer ..... *Papaipema purpurifascia* (G. & R.)
columbine leaf miner .. *Phytomyza minuscula* Gour.
common cattle grub ..... *Hypoderma lineatum* (De Vill.)
common malaria mosquito ..... *Anopheles quadrimaculatus* Say
Comstock mealybug ..... *Pseudococcus comstocki* (Kuw.)
conchuela ..... *Chlorochroa ligata* (Say)
confused flour beetle ..... *Tribolium confusum* Duv.
convergent lady beetle ..... *Hippodamia convergens* Guér.
Cooley spruce gall aphid ..... *Chermes cooleyi* Gill.
corn blotch leaf miner .. *Agromyza parvicornis* Loew
corn earworm ..... *Heliothis armigera* (Hbn.)
corn flea beetle ..... *Chaetocnema pulicaria* Melsh.
corn leaf aphid ..... *Aphis maidis* Fitch
corn root aphid ... *Anuraphis maidi-radicis* (Forbes)
corn root webworm ... *Crambus caliginosellus* Clem.
corn rootworm ..... *Diabrotica longicornis* (Say)
corn sap beetle ..... *Carpophilus dimidiatus* (F.)
corn silk beetle ..... *Luperodes brunneus* (Crotch)
cornfield ant ..... *Lasius niger alienus americanus* Emery
cotton aphid ..... *Aphis gossypii* Glov.
cotton blister mite .... *Cecidophyes gossypii* (Banks)
cotton fleahopper ..... *Psallus seriatus* (Reut.)
cotton lace bug ..... *Corythucha gossypii* (F.)
cotton leaf miner ..... *Nepticula gossypii* F. & L.
cotton leaf perforator ..... *Bucculatrix thurberiella* Busck
cotton leafworm ..... *Alabama argillacea* (Hbn.)
cotton square borer ..... *Strymon melinus* (Hbn.)
cotton stainer ..... *Dysdercus suturellus* (H. S.)
cottonwood borer ..... *Plectrodera scalator* (F.)
cottonwood dagger moth ..... *Acronycta lepusculina* Guen.
cottonwood leaf beetle ..... *Chrysomela scripta* F.
cottony-cushion scale ..... *Icerya purchasi* Mask.
cottony maple scale ..... *Pulvinaria vitis* (L.)
cottony peach scale ..... *Pulvinaria amygdali* Ckll.
coulee cricket ..... *Peranabrus scabricollis* (Thos.)
cowpea aphid ..... *Aphis medicaginis* Koch
cowpea curculio ..... *Chalcodermus aeneus* Boh.
cowpea weevil ..... *Callosobruchus maculatus* (F.)
crab-hole mosquito ..... *Deinocerites cancer* Theob.
crab louse ..... *Phthirus pubis* (L).
cranberry fruitworm ..... *Mineola vaccinii* (Riley)
cranberry girdler ..... *Crambus topiarius* Zell.
cranberry rootworm ... *Rhabdopterus picipes* (Oliv.)
cranberry spanworm ..... *Anavitrinella pampinaria* (Guen.)
cranberry weevil ..... *Anthonomus musculus* Say
crapemyrtle aphid ..... *Myzocallis kahawaloukalani* Kirk.
crazy ant ..... *Paratrechina longicornis* (Latr.)
crescent-marked lily aphid ..... *Myzus circumflexus* (Buck.)
crinkled flannel moth .. *Megalopyge crispata* (Pack.)
cross-striped cabbageworm ..... *Evergestis rimosalis* (Guen.)
Cuban cockroach ..... *Panchlora cubensis* Sauss.
Cuban-laurel thrips ..... *Gynaikothrips ficorum* (March.)
curled rose sawfly ..... *Allantus cinctus* (L.)
currant aphid ..... *Capitophorus ribis* (L.)
currant borer ..... *Ramosia tipuliformis* (Clerck)
currant bud mite ..... *Cecidophyes ribis* (Nal.)
currant fruit fly ..... *Epochra canadensis* Loew
currant fruit weevil ..... *Pseudanthonomus validus* Dietz
currant spanworm ..... *Itame ribearia* (Fitch)
currant stem girdler ..... *Janus integer* (Nort.)
cyclamen mite ..... *Tarsonemus pallidus* Banks
cynthia moth ..... *Philosamia cynthia* (Drury)

dark mealworm ..... *Tenebrio obscurus* F.
dark-sided cutworm ..... *Euxoa messoria* (Harr.)
date mite ..... *Paratetranychus simplex* (Banks)
datebug ..... *Asarcopus palmarum* Horv.
deodar weevil ..... *Pissodes nemorensis* Germ.
depluming mite ..... *Cnemidocoptes gallinae* (Raill.)
depressed flour beetle .. *Palorus subdepressus* (Woll.)
desert corn flea beetle .... *Chaetocnema ectypa* Horn
devastating grasshopper ..... *Melanoplus mexicanus devastator* Scudd.
diamondback moth ... *Plutella maculipennis* (Curt.)
dictyospermum scale ..... *Chrysomphalus dictyospermi* (Morg.)
differential grasshopper ..... *Melanoplus differentialis* (Thos.)
dingy cutworm ..... *Feltia subgothica* (Haw.)
dobsonfly ..... *Corydalus cornutus* (L).
dock sawfly ..... *Ametastegia glabrata* (Fall.)
dodder gall weevil .... *Smicronyx sculpticollis* Casey
dog flea ..... *Ctenocephalides canis* (Curt.)
dog follicle mite ..... *Demodex canis* Leydig
dogwood borer ..... *Thamnosphecia scitula* (Harr.)
dogwood club-gall midge ..... *Mycodiplosis alternata* Felt
dogwood scale ..... *Chionaspis corni* Cooley
dogwood spittlebug ..... *Clastoptera proteus* Fitch
dogwood twig borer ..... *Oberea tripunctata* (Swed.)
Douglas-fir beetle ..... *Dendroctonus pseudotsugae* Hopk.
Douglas-fir engraver ..... *Scolytus unispinosus* Lec.
Douglas-fir tussock moth ..... *Hemerocampa pseudotsugata* McD.
dried-fruit beetle ..... *Carpophilus hemipterus* (L.)
dried-fruit mite ..... *Carpoglyphus lactis* (L.)

dried-fruit moth.....*Vitula serratilineella* Rag.
drug-store beetle.....*Stegobium paniceum* (L.)
dry-land wireworm.....*Ludius inflatus* (Say)
dusky birch sawfly.....*Croesus latitarsus* Nort.

ear tick.....*Otobius megnini* (Dugès)
eastern field wireworm.....*Limonius agonus* (Say)
eastern larch beetle.....*Dendroctonus simplex* Lec.
eastern lubber grasshopper.....*Romalea microptera* (Beauv.)
eastern raspberry fruitworm....*Byturus rubi* Barber
eastern spruce beetle.....*Dendroctonus piceaperda* Hopk.
eastern spruce gall aphid.....*Chermes abietis* L.
eastern tent caterpillar.....*Malacosoma americanum* (F.)
eggplant flea beetle.....*Epitrix fuscula* Crotch
eggplant lace bug.....*Gargaphia solani* Heid.
eggplant leaf miner.....*Keiferia glochinella* (Zell.)
eight-spotted forester.....*Alypia octomaculata* (F.)
elder shoot borer.....*Achatodes zeae* (Harr.)
elm borer.....*Saperda tridentata* Oliv.
elm calligrapha.....*Calligrapha scalaris* (Lec.)
elm casebearer....*Coleophora limosipennella* (Dup.)
elm cockscomb gall.....*Colopha ulmicola* (Fitch)
elm lace bug.....*Corythucha ulmi* O. & D.
elm leaf aphid.....*Myzocallis ulmifolii* (Monell)
elm leaf beetle....*Galerucella xanthomelaena* (Schr.)
elm leaf miner.....*Fenusa ulmi* Sund.
elm sawfly.....*Cimbex americana* Leach
elm scurfy scale.....*Chionaspis americana* Johns.
elm spanworm.....*Ennomos subsignarius* (Hbn.)
elongate flea beetle.....*Systena elongata* (F.)
Engelmann spruce beetle.....*Dendroctonus engelmanni* Hopk.
Engelmann spruce weevil.....*Pissodes engelmanni* Hopk.
English grain aphid.....*Macrosiphum granarium* (Kby.)
ermine moth.....*Hyponomeuta padella* (L.)
euonymus scale.....*Unaspis euonymi* (Comst.)
European alder leaf miner.....*Fenusa dohrnii* (Tisch.)
European apple sawfly.....*Hoplocampa testudinea* (Klug)
European chicken flea.....*Ceratophyllus gallinae* (Schr.)
European corn borer.....*Pyrausta nubilalis* (Hbn.)
European earwig.....*Forficula auricularia* L.
European elm scale.....*Gossyparia spuria* (Mod.)
European fruit lecanium....*Lecanium corni* Bouché
European fruit scale.....*Aspidiotus ostreaeformis* Curt.
European grain moth.....*Nemapogon granella* (L.)
European honeysuckle leaf roller.....*Harpipteryx xylostella* (L.)
European mantis.....*Mantis religiosa* L.
European peach scale.....*Lecanium persicae* (F.)
European pine shoot moth.....*Rhyacionia buoliana* (Schiff.)
European red mite.....*Paratetranychus pilosus* (C. & F.)
European spruce beetle.....*Dendroctonus micans* (Kug.)
European spruce sawfly....*Diprion hercyniae*(Htg.)
European wheat stem sawfly.....*Cephus pygmaeus* (L.)
eye-spotted bud moth..*Spilonota ocellana* (D. & S.)
eyed click beetle.....*Alaus oculatus* (L.)

fall armyworm.....*Laphygma frugiperda* (A. & S.)
fall cankerworm.....*Alsophila pometaria* (Harr.)
fall webworm.....*Hyphantria cunea* (Drury)
false chinch bug.....*Nysius ericae* (Schill.)
false potato beetle.....*Leptinotarsa juncta* (Germ.)
false stable fly.....*Muscina stabulans* (Fall.)
fern scale.....*Pinnaspis aspidistrae* (Sign.)
field cricket.....*Acheta assimilis* F.
fiery hunter.....*Calosoma calidum* (F.)
fig mite.....*Aceria ficus* (Cotte)
fig scale.....*Lepidosaphes ficus* (Sign.)
filament bearer.....*Nematocampa limbata* (Haw.)
filbert bud mite.....*Phytoptus avellanae* Nal.
filbert weevil.....*Curculio uniformis* (Lec.)
filbertworm.....*Melissopus latiferreanus* (Wlsm.)
fir engraver.....*Scolytus ventralis* Lec.
fire ant.....*Solenopsis geminata* (F.)
firebrat.....*Thermobia domestica* (Pack.)
flat grain beetle.....*Laemophloeus minutus* (Oliv.)
flatheaded apple tree borer.....*Chrysobothris femorata* (Oliv.)
flatheaded fir borer.....*Melanophila drummondi* (Kby.)
flax bollworm.....*Heliothis ononis* (Schiff.)
floodwater mosquito.....*Aedes sticticus* (Meig.)
Florida carpenter ant.....*Camponotus abdominalis floridanus* (Buckl.)
Florida fern caterpillar.....*Callopistria floridensis* (Guen.)
Florida harvester ant..*Pogonomyrmex badius* (Latr.)
Florida red scale.....*Chrysomphalus aonidum* (L.)
Florida wax scale.....*Ceroplastes floridensis* Comst.
flower thrips.....*Frankliniella tritici* (Fitch)
fluff louse.....*Goniocotes hologaster* Nitz.
forage looper.....*Caenurgina erechtea* (Cram.)
Forbes scale.....*Aspidiotus forbesi* Johns.
forest tent caterpillar....*Malacosoma disstria* Hbn.
fork-tailed bush katydid...*Scudderia furcata* Brun.
four-lined plant bug....*Poecilocapsus lineatus* (F.)
four-spotted tree cricket.....*Oecanthus nigricornis quadripunctatus* Beut.
fowl tick.....*Argas persicus* (Oken)
foxglove aphid.....*Myzus convolvuli* (Kltb.)
frit fly.....*Oscinella frit* (L.)
fruit tree leaf roller....*Archips argyrospila* (Wlkr.)
Fuller rose beetle....*Pantomorus godmani* (Crotch)
furniture carpet beetle...*Anthrenus vorax* (Waterh.)

gall-making maple borer..*Xylotrechus aceris* Fisher
garden centipede..*Scutigerella immaculata* (Newp.)
garden fleahopper.....*Halticus bracteatus* (Say)
garden springtail.....*Bourletiella hortensis* (Fitch)
garden webworm.....*Loxostege similalis* (Guen.)
German cockroach.....*Blatella germanica* (L.)
giant hornet.....*Vespa crabro germana* Christ
giant stag beetle.....*Lucanus elaphus* F.
giant water bug.....*Lethocerus americanus* (Leidy)
gladiolus thrips.....*Taeniothrips simplex* (Mor.)
glassy cutworm.....*Crymodes devastator* (Brace)
globose scale.....*Lecanium prunastri* (Fonsc.)
gloomy scale..*Chrysomphalus tenebricosus* (Comst.)
Glover scale.....*Lepidosaphes gloverii* (Pack.)
goat follicle mite.....*Demodex caprae* Raill.
golden-eye lacewing.....*Chrysopa oculata* Say
golden spider beetle.....*Niptus hololeucus* (Fald.)
golden tortoise beetle.....*Metriona bicolor* (F.)
goldenglow aphid..*Macrosiphum rudbeckiae* (Fitch)
gooseberry fruitworm..*Zophodia convolutella* (Hbn.)
gooseberry witchbroom aphid.....*Kakimia houghtonensis* (Troop)
grain mite.....*Acarus siro* (L.)
grain rust mite.....*Abacarus hystrix* (Nal.)
grain thrips.....*Limothrips cerealium* Hal.
granary weevil.....*Sitophilus granarius* (L.)
granulate cutworm.....*Feltia subterranea* (F.)

grape berry moth.....*Polychrosis viteana* (Clem.)
grape blossom midge...*Contarinia johnsoni* (Sling.)
grape cane gall maker.....
.....*Ampeloglypter sesostris* (Lec.)
grape colaspis.....*Colaspis flavida* (Say)
grape curculio.....*Craponius inaequalis* (Say)
grape erineum mite.....*Eriophyes vitis* (Pgst.)
grape flea beetle.....*Altica chalybea* (Ill.)
grape leaf folder.....*Desmia funeralis* (Hbn.)
grape leaf skeletonizer.....
.....*Harrisina americana* (Guér.)
grape mealybug....*Pseudococcus maritimus* (Ehrh.)
grape phylloxera.....*Phylloxera vitifoliae* (Fitch)
grape plume moth.....
.....*Pterophorus periscelidactylus* Fitch
grape root borer.....*Vitacea polistiformis* (Harr.)
grape rootworm.....*Fidia viticida* Walsh
grape sawfly.....*Erythraspides pygmaea* (Say)
grape scale.....*Aspidiotus uvae* Comst.
grape seed chalcid.....*Eroxysoma vitis* (Saund.)
grape trunk borer.....
.....*Clytoleptus albofasciatus* (C. &G.)
grape whitefly.....*Trialeurodes vittatus* (Quaint.)
grapevine aphid.....*Aphis illinoisensis* Shimer
grapevine looper.....*Lygris diversilineata* (Hbn.)
grass sawfly....*Pachynematus extensicornis* (Nort.)
grass thrips.....*Anaphothrips obscurus* (Müll.)
grasshopper bee fly.....*Systoechus vulgaris* Loew
grasshopper maggot.....*Sarcophaga kellyi* Ald.
gray-banded leaf roller.....
.....*Argyrotaenia mariana* (Fern.)
gray blister beetle.....*Epicauta cinerea* (Forst.)
Great Basin wireworm.....
.....*Ludius pruininus noxius* (Hyslop)
greedy scale.....*Aspidiotus camelliae* Sign.
green budworm.....*Hedia variegana* (Hbn.)
green cloverworm.....*Plathypena scabra* (F.)
green fruitworm.....*Lithophane antennata* (Wlkr.)
green-headed spruce sawfly.....
.....*Pikonema dimmocki* (Cress.)
green June beetle.....*Cotinis nitida* (L.)
green meadow locust.....
.....*Chortophaga viridifasciata* (Deg.)
green peach aphid.....*Myzus persicae* (Sulz.)
green rose chafer.....*Dichelonyx backi* (Kby.)
green scale.....*Coccus viridis* (Green)
green shield scale.....*Pulvinaria psidii* Mask.
green stink bug.....*Acrosternum hilare* (Say)
green-striped mapleworm...*Anisota rubicunda* (F.)
greenbug.....*Toxoptera graminum* (Rond.)
greenhouse leaf tier...*Phlyctaenia rubigalis* (Guen.)
greenhouse orthezia.....*Orthezia insignis* Browne
greenhouse stone cricket.....
.....*Tachycines asynamorus* Adel.
greenhouse thrips.....
.....*Heliothrips haemorrhoidalis* (Bouché)
greenhouse whitefly.....
.....*Trialeurodes vaporariorum* (Westw.)
gregarious oak leaf miner.....
.....*Cameraria cincinnatiella* (Chamb.)
ground mealybug.....*Rhizoecus terrestris* (Newst.)
Gulf Coast tick.....*Amblyomma maculatum* Koch
Gulf wireworm.....*Heteroderes laurentii* (Guér)
gypsy moth.....*Porthetria dispar* (L.)

hackberry engraver.....*Scolytus muticus* Say
hackberry lace bug.....*Corythucha celtidis* O. & D.
hackberry nipple gall.....
.....*Pachypsylla celtidis-mamma* (Flet.)
hag moth.....*Phobetron pithecium* (A. & S.)
hairy chinch bug.....*Blissus hirtus* Montd.
hairy spider beetle.....*Ptinus villiger*(Reit.)
Hall scale.....*Nilotaspis halli* (Green)
harlequin bug.....*Murgantia histrionica* (Hahn)
Hawaiian beet webworm....*Hymenia recurvalis* (F.)
hawthorn lace bug.....*Corythucha cydoniae* (Fitch)
head louse.....*Pediculus humanus humanus* L.
hellgrammite.....*Corydalus cornutus* (L.)
hemispherical scale.....
.....*Saissetia hemisphaerica* (Targ.)
hemlock borer.....*Melanophila fulvoguttata* (Harr.)
hemlock looper.....*Lambdina fiscellaria* (Guen.)
hemlock sawfly.....*Neodiprion tsugae* Midd.
hemlock scale.....*Aspidiotus ithacae* (Ferris)
hessian fly.....*Phytophaga destructor* (Say)
hickory bark beetle.....*Scolytus quadrispinosus* Say
hickory horned devil.....*Citheronia regalis* (F.)
hickory leaf roller...*Argyrotaenia juglandana* (Fern.)
hickory plant bug.....*Neolygus caryae* Kngt.
hickory shuckworm.....*Laspeyresia caryana* (Fitch)
hickory tussock moth.....*Halisidota caryae* (Harr.)
hide beetle.....*Dermestes maculatus* Deg.
hog follicle mite.....*Demodex phylloides* Csokor
hog louse.....*Haematopinus adventicius* Neum.
holly leaf miner.....*Phytomyza ilicis* (Curtis)
holly scale.....*Aspidiotus britannicus* Newst.
hollyhock plant bug.....
.....*Melanotrichus althaeae* (Hussey)
honey bee.....*Apis mellifera* L.
honeysuckle sawfly.....*Zaraea inflata* Nort.
hop aphid.....*Phorodon humuli* (Schr.)
hop flea beetle.....*Psylliodes punctulata* Melsh.
hop looper.....*Hypena humuli* (Harr.)
hop plant bug.....*Paracalocoris hawleyi* Kngt.
horn fly.....*Siphona irritans* (L.)
horned passalus.....*Popilius disjunctus* (Ill.)
horned squash bug.....*Anasa armigera* (Say)
hornet moth.....*Aegeria apiformis* (Clerck)
horse biting louse.....*Bovicola equi* (L.)
horse bot fly.....*Gasterophilus intestinalis* (Deg.)
horse follicle mite.....*Demodex equi* Raill.
horse sucking louse.....*Haematopinus asini* (L.)
horseradish flea beetle.....
.....*Phyllotreta armoraciae* (Koch)
house centipede.....*Scutigera cleoptrata* (L.)
house cricket.....*Acheta domestica* L.
house fly.....*Musca domestica* L.
Howard scale.....*Aspidiotus howardi* Ckll.
human flea.....*Pulex irritans* L.
human bot fly.....*Dermatobia hominis* (L., Jr.)

imbricated snout beetle.....
.....*Epicaerus imbricatus* (Say)
imperial moth.....*Eacles imperialis* (Drury)
imported cabbageworm.....*Pieris rapae* (L.)
imported currantworm.....*Nematus ribesii* (Scop.)
imported willow leaf beetle.....
.....*Plagiodera versicolora* (Laich.)
Indian-meal moth.....*Plodia interpunctella* (Hbn.)
introduced pine sawfly.....*Diprion simile* (Htg.)
io moth.....*Automeris io* (F.)
iris borer.....*Macronoctua onusta* Grote
iris thrips.....*Bregmatothrips iridis* Watson
iris weevil.....*Mononychus vulpeculus* (F.)
Italian pear scale...*Epidiaspis piricola* (Del Guer.)
itch mite.....*Sarcoptes scabiei* (Deg.)
ivy aphid.....*Aphis hederae* Kltb.

jack-pine sawfly.....*Neodiprion banksianae* Roh.
Japanese beetle.....*Popillia japonica* Newm.
Jeffrey pine beetle.....*Dendroctonus jeffreyi* Hopk.
Jerusalem cricket.....*Stenopelmatus fuscus* Hald.
juniper scale.....*Diaspis carueli* Targ.
juniper webworm.....*Dichomeris marginella* (F.)

koa seedworm ..... *Cryptophlebia illepida* (Butl.)

lantana lace bug ..... *Teleonemia lantanae* Dist.
lantana leaf miner ..... *Cremastobombycia lantanella* Busck
lantana plume moth ..... *Platyptilia pusillodactyla* (Wlkr.)
lantana seed fly ..... *Agromyza lantanae* Frog.
lappet moth ..... *Epicnaptera americana* (Harr.)
larch casebearer ..... *Coleophora laricella* (Hbn.)
larch sawfly ..... *Pristiphora erichsonii* (Htg.)
larder beetle ..... *Dermestes lardarius* L.
large aspen tortrix ..... *Archips conflictana* (Wlkr.)
large chestnut weevil ..... *Curculio proboscideus* F.
large chicken louse ..... *Goniodes gigas* (Tasch.)
large duck louse ..... *Trinoton querquedulae* (L.)
large milkweed bug ..... *Oncopeltus fasciatus* (Dall.)
large turkey louse ..... *Virgula meleagridis* (L.)
larger canna leaf roller ..... *Calpodes ethlius* (Stoll)
larger elm leaf beetle ..... *Monocesta coryli* (Say)
larger Mexican pine beetle ..... *Dendroctonus parallelocollis* Chap.
larger shot-hole borer ..... *Scolytus sulcatus* Lec.
larger yellow ant ..... *Lasius interjectus* Mayr
larkspur leaf miner ..... *Phytomyza delphiniae* Frost
latrine fly ..... *Fannia scalaris* (F.)
lead cable borer ..... *Scobicia declivis* (Lec.)
leaf crumpler ..... *Mineola indigenella* (Zell.)
leaf-footed bug ..... *Leptoglossus phyllopus* (L.)
leopard moth ..... *Zeuzera pyrina* (L.)
lespedeza webworm ..... *Tetralopha scortealis* (Led.)
lesser appleworm ..... *Grapholitha prunivora* (Walsh)
lesser bud moth ..... *Recurvaria nanella* (Hbn.)
lesser bulb fly ..... *Eumerus tuberculatus* Rond.
lesser clover leaf weevil ..... *Hypera nigrirostris* (F.)
lesser cornstalk borer ..... *Elasmopalpus lignosellus* (Zell.)
lesser grain borer ..... *Rhyzopertha dominica* (F.)
lesser mealworm ..... *Alphitobius diaperinus* (Panz.)
lesser migratory grasshopper ..... *Melanoplus mexicanus mexicanus* (Sauss.)
lesser peach tree borer ..... *Synanthedon pictipes* (G. & R.)
lesser wax moth ..... *Achroia grisella* (F.)
lilac borer ..... *Podosesia syringae syringae* (Harr.)
lilac leaf miner ..... *Gracilaria syringella* (F.)
lily bulb thrips ..... *Liothrips vaneeckei* Pries.
lily weevil ..... *Agasphaerops nigra* Horn
lima-bean pod borer ..... *Etiella zinckenella* (Treit.)
lima-bean vine borer ..... *Monoptilota pergratialis* (Hulst)
linden borer ..... *Saperda vestita* Say
linden looper ..... *Erannis tiliaria* (Harr.)
lined spittlebug ..... *Philaenus lineatus* (L.)
lined stalk borer ..... *Oligia fractilinea* (Grote)
little black ant ..... *Monomorium minimum* (Buckl.)
little carpenterworm ..... *Prionoxystus macmurtrei* (Guér.)
little fire ant ..... *Wasmannia auropunctata* (Roger)
little house fly ..... *Fannia canicularis* (L.)
locust borer ..... *Megacyllene robiniae* (Forst.)
locust leaf miner ..... *Chalepus dorsalis* Thunb.
locust leaf roller ..... *Salebria subcaesiella* (Clem.)
locust twig borer ..... *Ecdytolopha insiticiana* Zell.
lodgepole cone beetle ..... *Conophthorus contortae* Hopk.
lodgepole needle miner ..... *Recurvaria milleri* Busck
lodgepole-pine beetle ..... *Dendroctonus murrayanae* Hopk.
lodgepole sawfly ..... *Neodiprion burkei* Midd.
lone star tick ..... *Amblyomma americanum* (L.)
long-nosed cattle louse ..... *Linognathus vituli* (L.)
long-tailed mealybug ..... *Pseudococcus adonidum* (L.)
lubber grasshopper ..... *Brachystola magna* (Gir.)
luna moth ..... *Tropaea luna* (L.)

magnolia scale ..... *Neolecanium cornuparvum* (Thro)
maize billbug ..... *Calendra maidis* (Chitt.)
mango weevil ..... *Cryptorhynchus mangiferae* (F.)
maple bladder-gall mite ..... *Vasates quadripedes* Shimer
maple callus borer ..... *Sylvora acerni* (Clem.)
maple leaf cutter ..... *Paraclemensia acerifoliella* (Fitch)
maple petiole borer ..... *Caulocampus acericaulis* (MacG.)
maple trumpet skeletonizer ..... *Epinotia aceriella* (Clem.)
margined blister beetle ..... *Epicauta solani* Werner
masked hunter ..... *Reduvius personatus* (L.)
meadow plant bug ..... *Miris dolabratus* (L.)
meadow spittlebug ..... *Philaenus leucophthalmus* (L.)
meal moth ..... *Pyralis farinalis* (L.)
mealy plum aphid ..... *Hyalopterus arundinis* (F.)
Mediterranean flour moth ..... *Ephestia kühniella* Zell.
Mediterranean fruit fly ..... *Ceratitis capitata* (Wied.)
melon aphid ..... *Aphis gossypii* Glov.
melon fly ..... *Dacus cucurbitae* (Coq.)
melonworm ..... *Diaphania hyalinata* (L.)
Mexican bean beetle ..... *Epilachna varivestis* Muls.
Mexican fruit fly ..... *Anastrepha ludens* (Loew)
Mexican mealybug ..... *Phenacoccus gossypii* T. & C.
mimosa webworm ..... *Homadaula albizziae* (Clarke)
mining scale ..... *Howardia biclavis* (Comst.)
monarch butterfly ..... *Danaus plexippus* (L.)
Monterey-pine cone beetle ..... *Conophthorus radiatae* Hopk.
Monterey-pine weevil ..... *Pissodes radiatae* Hopk.
Mormon cricket ..... *Anabrus simplex* Hald.
morning-glory leaf miner ..... *Bedellia somnulentella* (Zell.)
mossy rose gall ..... *Diplolepis rosae* (L.)
mottled tortoise beetle ..... *Deloyala guttata* (Oliv.)
mountain pine beetle ..... *Dendroctonus monticolae* Hopk.
mountainash sawfly ..... *Pristiphora geniculata* (Htg.)
mourning-cloak butterfly ..... *Nymphalis antiopa* (L.)
mulberry whitefly ..... *Tetraleurodes mori* (Quaint.)
mullein thrips ..... *Neoheegeria verbasci* (Osb.)
mushroom mite ..... *Tyrophagus lintneri* (Osb.)

Nantucket pine tip moth ..... *Rhyacionia frustrana* (Comst.)
narcissus bulb fly ..... *Lampetia equestris* (F.)
narrow-winged mantis ..... *Tenodera angustipennis* Sauss.
native elm bark beetle ..... *Hylurgopinus rufipes* (Eichh.)
navel orangeworm ..... *Myelois venipars* Dyar
negro bug ..... *Corimelaena pulicaria* (Germ.)
New Guinea sugarcane weevil ..... *Rhabdoscelus obscurus* (Bdvl.)
New York weevil ..... *Ithycerus noveboracensis* (Forst.)
northeastern sawyer ..... *Monochamus notatus* (Drury)
northern cattle grub ..... *Hypoderma bovis* (Deg.)
northern fowl mite ..... *Liponyssus silviarum* (C. & F.)
northern house mosquito ..... *Culex pipiens* L.
northern mole cricket ..... *Gryllotalpa hexadactyla* Perty
northwest coast mosquito ..... *Aedes aboriginis* Dyar
northwestern floodwater mosquito ..... *Aedes lateralis* (Meig.)
Norway-maple aphid ..... *Periphyllus lyropictus* (Kess.)
nose bot fly ..... *Gasterophilus haemorrhoidalis* (L.)

nutgrass armyworm....*Laphygma exempta* (Wlkr.)
Nuttall blister beetle.....*Lytta nuttalli* Say

oak sapling borer.....*Goes tesselatus* (Hald.)
oak skeletonizer.....*Bucculatrix ainsliella* Murtf.
oak timberworm.....*Arrhenodes minutus* (Drury)
oblique-banded leaf roller.....
.....*Archips rosaceana* (Harr.)
obscure scale.....*Chrysomphalus obscurus* (Comst.)
odorous house ant.....*Tapinoma sessile* (Say)
old house borer.....*Hylotrupes bajulus* (L.)
oleander scale.....*Aspidiotus hederae* (Vallot)
olive fruit fly.....*Dacus oleae* (Gmel.)
olive scale.....*Parlatoria oleae* (Colvée)
omnivorous leaf tier.....*Cnephasia longana* (Haw.)
onion maggot.....*Hylemya antiqua* (Meig.)
onion plant bug.....*Labopidea allii* Kngt.
onion thrips.....*Thrips tabaci* Lind.
orange-dog.....*Papilio cresphontes* Cram.
orange-striped oakworm.....
.....*Anisota senatoria* (A. & S.)
orange tortrix.....*Argyrotaenia citrana* (Fern.)
orchidfly.....*Eurytoma orchidearum* (Westw.)
Oregon fir sawyer...*Monochamus oregonensis* (Lec.)
Oregon wireworm.....*Melanotus oregonensis* (Lec.)
oriental beetle.....*Anomala orientalis* Waterh.
oriental cockroach.....*Blatta orientalis* L.
oriental fruit moth.....*Grapholitha molesta* (Busck)
oriental house fly.....*Musca vicina* Macq.
oriental moth.....*Cnidocampa flavescens* (Wlkr.)
oriental rat flea.....*Xenopsylla cheopis* (Rothsch.)
oystershell scale.....*Lepidosaphes ulmi* (L.)

Pacific Coast tick..*Dermacentor occidentalis* Neum.
Pacific Coast wireworm.....*Limonius canus* Lec.
Pacific flatheaded borer...*Chrysobothris mali* Horn
Pacific mite.....*Tetranychus pacificus* McG.
Packard grasshopper..*Melanoplus packardii* Scudd.
painted beauty.....*Vanessa virginiensis* (Drury)
painted hickory borer..*Megacyllene caryae* (Gahan)
painted-lady.....*Vanessa cardui* (L.)
pale-sided cutworm.....*Agrotis malefida* Guen.
pale-striped flea beetle.....*Systena blanda* Melsh.
pale tussock moth...*Halisidota tessellaris* (A. & S.)
pale western cutworm.....*Agrotis orthogonia* Morr.
pales weevil.....*Hylobius pales* (Hbst.)
palm leaf skeletonizer.....
.....*Homaledra sabalella* (Chamb.)
palmerworm.....*Dichomeris ligulella* Hbn.
pandora moth.....*Coloradia pandora* Blake
papaya fruit fly.....*Toxotrypana curvicauda* Gerst.
parlatoria date scale..*Parlatoria blanchardi* (Targ.)
parsleyworm.....*Papilio ajax* L.
parsnip webworm.....*Depressaria heracliana* (L.)
pavement ant.....*Tetramorium caespitum* (L.)
pea aphid.....*Macrosiphum pisi* (Kltb.)
pea leaf weevil.....*Sitona lineata* (L.)
pea moth.....*Laspeyresia nigricana* (Steph.)
pea weevil.....*Bruchus pisorum* (L.)
peach bark beetle....*Phloeotribus liminaris* (Harr.)
peach silver mite.....*Vasates cornutus* (Banks)
peach tree borer.....*Sanninoidea exitiosa* (Say)
peach twig borer.....*Anarsia lineatella* Zell.
pear borer.....*Thamnosphecia pyri* (Harr.)
pear fruit borer.....*Nephopteryx rubrizonella* Rag.
pear leaf blister mite.....*Eriophyes pyri* (Pgst.)
pear midge.....*Contarinia pyrivora* (Riley)
pear plant bug.....*Neolygus communis* (Kngt.)
pear psylla.....*Psylla pyricola* Foerst.
pear rust mite.....*Epitrimerus pyri* (Nal.)
pear-slug.....*Caliroa cerasi* (L.)
pear thrips.....*Taeniothrips inconsequens* (Uzel)
pecan bud moth.....*Gretchena bolliana* (Sling.)
pecan carpenterworm.....*Cossula magnifica* (Stkr.)
pecan cigar casebearer.....
.....*Coleophora caryaefoliella* Clem.
pecan leaf casebearer....*Acrobasis juglandis* (LeB.)
pecan leaf phylloxera.....*Phylloxera notabilis* Perg.
pecan leafroll mite.....*Aceria caryae* (Keif.)
pecan nut casebearer.....*Acrobasis caryae* Grote
pecan phylloxera.....*Phylloxera devastatrix* Perg.
pecan weevil.....*Curculio caryae* (Horn)
pepper and salt moth..*Amphidasis cognataria* Guen.
pepper weevil.....*Anthonomus eugenii* Cano
peppergrass beetle.....*Galeruca browni* Blake
periodical cicada.....*Magicicada septendecim* (L.)
persimmon borer.....*Sannina uroceriformis* Wlkr.
persimmon psylla.....*Trioza diospyri* (Ashm.)
Pharaoh ant.....*Monomorium pharaonis* (L.)
phlox plant bug.....*Lopidea davisi* Kngt.
pickleworm.....*Diaphania nitidalis* (Stoll)
pigeon fly.....*Pseudolynchia canariensis* (Macq.)
pigeon tremex.....*Tremex columba* (L.)
pine bark aphid.....*Pineus strobi* (Htg.)
pine bud mite.....*Phytoptus pini* Nal.
pine butterfly.....*Neophasia menapia* (F. & F.)
pine chafer.....*Anomala oblivia* Horn
pine engraver.....*Ips pini* (Say)
pine false webworm.....
.....*Acantholyda erythrocephala* (L.)
pine gall weevil.....*Podapion gallicola* Riley
pine needle miner...*Exoteleia pinifoliella* (Chamb.)
pine needle scale.....*Phenacaspis pinifoliae* (Fitch)
pine root collar weevil.....*Hylobius radicis* Buch.
pine spittlebug.....*Aphrophora parallela* (Say)
pine tortoise scale.....
.....*Toumeyella numismaticum* (P. & M.)
pine tube moth...*Argyrotaenia pinatubana* (Kearf.)
pine webworm.....*Tetralopha robustella* Zell.
pineapple mealybug..*Pseudococcus brevipes* (Ckll.)
pineapple scale.....*Diaspis bromeliae* (Kern.)
pineapple weevil.....*Metamasius ritchiei* Mshl.
pink bollworm....*Pectinophora gossypiella* (Saund.)
piñon cone beetle.....*Conophthorus edulis* Hopk.
pipevine swallowtail.....*Battus philenor* (L.)
pistol casebearer.....*Coleophora malivorella* Riley
pitch mass borer.....*Vespamima pini* (Kell.)
pitch twig moth.....*Petrova comstockiana* (Fern.)
pitcherplant mosquito....*Wyeomyia smithii* (Coq.)
plains false wireworm.....*Eleodes opaca* (Say)
plum curculio.....*Conotrachelus nenuphar* (Hbst.)
plum gouger.....*Anthonomus scutellaris* Lec.
plum leafhopper.....*Macropsis trimaculata* (Fitch)
plum web-spinning sawfly.....
.....*Neurotoma inconspicua* (Nort.)
polyphemus moth.....*Telea polyphemus* (Cram.)
ponderosa-pine cone beetle.....
.....*Conophthorus ponderosae* Hopk.
poplar and willow borer.....
.....*Cryptorhynchus lapathi* (L.)
poplar borer.....*Saperda calcarata* Say
poplar leaf-folding sawfly.....
.....*Pontania bozemani* Cooley
poplar tent maker.....*Ichthyura inclusa* Hbn.
poplar vagabond aphid.....
.....*Mordwilkoja vagabunda* (Walsh)
potato aphid.....*Macrosiphum solanifolii* (Ashm.)
potato flea beetle.....*Epitrix cucumeris* (Harr.)
potato leafhopper.....*Empoasca fabae* (Harr.)
potato psyllid.....*Paratrioza cockerelli* (Sulc)
potato scab gnat.....*Pnyxia scabiei* (Hopk.)
potato stalk borer.....*Tricholaris trinotata* (Say)
potato stem borer.....*Hydroecia micacea* (Esp.)

potato tuberworm ..... *Gnorimoschema operculella* (Zell.)
poultry bug ..... *Haematosiphon inodorus* (Dugès)
prairie flea beetle ..... *Altica canadensis* (Gent.)
prairie grain wireworm ..... *Ctenicera aereipennis destructor* (Brown)
privet aphid ..... *Myzus ligustri* (Mosley)
privet leaf miner ..... *Gracilaria cuculipennella* (Hbn.)
promethea moth ..... *Callosamia promethea* (Drury)
Puget Sound wireworm ..... *Ctenicera aereipennis aereipennis* (Kby.)
purple scale ..... *Lepidosaphes beckii* (Newm.)
purple-spotted lily aphid ..... *Macrosiphum lilii* (Monell)
puss caterpillar ..... *Megalopyge opercularis* (A. & S.)
Putnam scale ..... *Aspidiotus ancylus* (Putn.)
pyramid ant ..... *Dorymyrmex pyramicus* (Roger)
pyriform scale ..... *Protopulvinaria pyriformis* (Ckll.)

quince curculio ..... *Conotrachelus crataegi* Walsh
quince treehopper ..... *Glossonotus crataegi* (Fitch)

rabbit louse ..... *Haemodipsus ventricosus* (Denny)
rabbit tick ..... *Haemaphysalis leporis-palustris* Pack.
ragweed borer ..... *Epiblema strenuana* (Wlkr.)
ragweed plant bug ..... *Chlamydatus associatus* (Uhl.)
raisin moth ..... *Ephestia figulilella* Greg.
range caterpillar ..... *Hemileuca oliviae* Ckll.
range crane fly ..... *Tipula simplex* Doane
rapid plant bug ..... *Adelphocoris rapidus* (Say)
raspberry cane borer ..... *Oberea bimaculata* (Oliv.)
raspberry cane maggot ..... *Pegomya rubivora* (Coq.)
raspberry leaf roller *Exartema permundanum* Clem.
raspberry root borer ..... *Bembecia marginata* (Harr.)
raspberry sawfly ..... *Blennocampa rubi* (Harr.)
rat flea ..... *Nosopsyllus fasciatus* (Bosc)
red-admiral ..... *Vanessa atalanta* (L.)
red-backed cutworm ..... *Euxoa ochrogaster* (Guen.)
red-banded leaf roller ..... *Argyrotaenia velutinana* (Wlkr.)
red-banded thrips ..... *Selenothrips rubrocinctus* (Giard)
red carpenter ant ..... *Camponotus herculeanus pennsylvanicus ferrugineus* (F.)
red date scale ..... *Phoenicococcus marlatti* Ckll.
red elm bark weevil ..... *Magdalis armicollis* (Say)
red flour beetle ..... *Tribolium castaneum* (Hbst.)
red harvester ant ..... *Pogonomyrmex barbatus* (F. Smith)
red-headed ash borer ..... *Neoclytus acuminatus* (F.)
red-headed pine sawfly ..... *Neodiprion lecontei* (Fitch)
red-humped caterpillar *Schizura concinna* (A. & S.)
red-legged flea beetle ..... *Derocrepis erythropus* (Melsh.)
red-legged grasshopper ..... *Melanoplus femur-rubrum* (Deg.)
red-legged ham beetle ..... *Necrobia rufipes* (Deg.)
red milkweed beetle ..... *Tetraopes tetrophthalmus* (Forst.)
red-necked cane borer ..... *Agrilus ruficollis* (F.)
red-necked peanutworm ..... *Stegasta bosquella* (Chamb.)
red-pine cone beetle ..... *Conophthorus resinosae* Hopk.
red-shouldered ham beetle ..... *Necrobia ruficollis* (F.)
red turnip beetle ..... *Entomoscelis americana* Brown
red turpentine beetle ..... *Dendroctonus valens* Lec.
red-winged pine beetle ..... *Dendroctonus rufipennis* (Kby.)
redberry mite ..... *Aceria essigi* (Hassan)
regal moth ..... *Citheronia regalis* (F.)
relapsing-fever tick ..... *Ornithodoros turicata* (Dugès)
resplendent shield bearer ..... *Coptodisca splendoriferella* (Clem.)
Rhodes-grass scale ..... *Antonina graminis* (Mask.)
rhododendron borer ..... *Ramosia rhododendri* (Beut.)
rhododendron lace bug ..... *Stephanitis rhododendri* Horv.
rhododendron whitefly ..... *Dialeurodes chittendeni* Laing
rhubarb curculio ..... *Lixus concavus* Say
rice stalk borer ..... *Chilo plejadellus* Zinck.
rice water weevil ..... *Lissorhoptrus simplex* (Say)
rice weevil ..... *Sitophilus oryza* (L.)
ring-legged earwig ..... *Euborellia annulipes* (Lucas)
Rocky Mountain grasshopper ..... *Melanoplus mexicanus spretus* (Walsh)
Rocky Mountain wood tick ..... *Dermacentor andersoni* Stiles
rose aphid ..... *Macrosiphum rosae* (L.)
rose chafer ..... *Macrodactylus subspinosus* (F.)
rose curculio ..... *Rhynchites bicolor* (F.)
rose leaf beetle ..... *Nodonota puncticollis* (Say)
rose leafhopper ..... *Typhlocyba rosae* (L.)
rose midge ..... *Dasyneura rhodophaga* (Coq.)
rose root gall ..... *Diplolepis radicum* (O. S.)
rose-slug ..... *Endelomyia aethiops* (F.)
rose scale ..... *Aulacaspis rosae* (Bouché)
rose stem girdler ..... *Agrilus communis* var. *rubicola* Abeille
rosy apple aphid ..... *Anuraphis roseus* Baker
roundheaded apple tree borer ..... *Saperda candida* F.
roundheaded fir borer ..... *Tetropium abietis* Fall
roundheaded pine beetle ..... *Dendroctonus convexifrons* Hopk.
rustic borer ..... *Xylotrechus colonus* (F.)
rusty grain beetle ..... *Laemophloeus ferrugineus* (Steph.)
rusty plum aphid ..... *Hysteroneura setariae* (Thos.)
rusty tussock moth ..... *Notolophus antiqua* (L.)

saddleback caterpillar ..... *Sibine stimulea* (Clem.)
saddled leafhopper ..... *Calladonus clitellarius* (Say)
saddled prominent ..... *Heterocampa guttivitta* (Wlkr.)
salt-marsh caterpillar ..... *Estigmene acrea* (Drury)
salt-marsh mosquito ..... *Aedes sollicitans* (Wlkr.)
San Jose scale ..... *Aspidiotus perniciosus* Comst.
sand wireworm ..... *Horistonotus uhlerii* Horn
sapwood timberworm ..... *Hylecoetus lugubris* Say
Saratoga spittlebug ..... *Aphrophora saratogensis* (Fitch)
satin moth ..... *Stilpnotia salicis* (L.)
saw-toothed grain beetle ..... *Oryzaephilus surinamensis* (L.)
Say blister beetle ..... *Pomphopoea sayi* (Lec.)
Say stink bug ..... *Chlorochroa sayi* Stål
scab mite ..... *Psoroptes equi* Gerv.
scaly-leg mite ..... *Cnemidocoptes mutans* (R. & L.)
screw-worm ..... *Callitroga americana* (C. & P.)
scurfy scale ..... *Chionaspis furfura* (Fitch)
secondary screw-worm ..... *Callitroga macellaria* (F.)
seed-corn beetle ..... *Agonoderus lecontei* Chaud.
seed-corn maggot ..... *Hylemya cilicrura* (Rond.)
sequoia pitch moth ..... *Vespamima sequoiae* (Hy. Edw.)
serpentine leaf miner ..... *Liriomyza pusilla* (Meig.)
shaft louse ..... *Menopon gallinae* (L.)
sheep bot fly ..... *Oestrus ovis* L.
sheep follicle mite ..... *Demodex canis* var. *ovis* Raill.
sheep scab mite ..... *Psoroptes ovis* (Her.)
sheep-tick ..... *Melophagus ovinus* (L.)
short-nosed cattle louse ..... *Haematopinus eurysternus* (Nitz.)
shot-hole borer ..... *Scolytus rugulosus* (Ratz.)

silkworm ..... *Bombyx mori* (L.)
silky ant ..... *Formica fusca* var. *subsericea* Say
silky cane weevil ..... *Metamasius sericeus* (Oliv.)
silver-spotted skipper ..... *Proteides clarus* (Cram.)
silverfish ..... *Lepisma saccharina* L.
sinuate pear tree borer ..... *Agrilus sinuatus* (Oliv.)
Sitka-spruce beetle ..... *Dendroctonus obesus* (Mann.)
Sitka-spruce weevil ..... *Pissodes sitchensis* Hopk.
six-spotted leafhopper ..... *Macrosteles divisus* (Uhl.)
six-spotted mite ..... *Tetranychus sexmaculatus* Riley
slender duck louse ..... *Anaticola crassicornis* (Scop.)
slender guinea-pig louse ..... *Gliricola porcelli* (L.)
slender pigeon louse ..... *Columbicola columbae* (L.)
small milkweed bug ..... *Lygaeus kalmii* Stål
small pigeon louse ..... *Goniocotes bidentatus* Scop.
smaller European elm bark beetle ..... *Scolytus multistriatus* (Marsh.)
smaller Mexican pine beetle ..... *Dendroctonus mexicanus* Hopk.
smaller yellow ant ..... *Lasius claviger* (Roger)
smartweed borer ..... *Pyrausta ainsliei* Heinr.
smeared dagger moth ..... *Acronycta oblinita* (A. & S.)
smut beetle ..... *Phalacrus politus* Melsh.
snowball aphid ..... *Anuraphis viburnicola* (Gill.)
snowy tree cricket ..... *Oecanthus niveus* (Deg.)
soft scale ..... *Coccus hesperidum* L.
solitary oak leaf miner ..... *Cameraria hamadryadella* (Clem.)
sorghum midge ..... *Contarinia sorghicola* (Coq.)
sorghum webworm ..... *Celama sorghiella* (Riley)
southern armyworm ..... *Prodenia eridania* (Cram.)
southern beet webworm ..... *Pachyzancla bipunctalis* (F.)
southern buffalo gnat ..... *Eusimulium pecuarum* (Riley)
southern cabbage worm ..... *Pieris protodice* B. & L.
southern corn rootworm ..... *Diabrotica duodecimpunctata* (F.)
southern cornstalk borer ..... *Diatraea crambidoides* (Grote)
southern fire ant ..... *Solenopsis xyloni* McCook
southern green stink bug ..... *Nezara viridula* (L.)
southern house mosquito ..... *Culex quinquefasciatus* Say
southern lyctus beetle ..... *Lyctus planicollis* Lec.
southern mole cricket ..... *Scapteriscus acletus* R. & H.
southern pine beetle ..... *Dendroctonus frontalis* Zimm
southern pine sawyer ..... *Monochamus titillator* (F.)
southern red mite ..... *Paratetranychus ilicis* (McG.)
southwestern corn borer. *Diatraea grandiosella* Dyar
southwestern pine beetle *Dendroctonus barberi* Hopk.
Spanish-fly ..... *Lytta vesicatoria* (L.)
spice-bush swallowtail ..... *Papilio troilus* L.
spinach flea beetle ..... *Disonycha xanthomelaena* (Dalm.)
spinach leaf miner ..... *Pegomya hyoscyami* (Panz.)
spined soldier bug ..... *Podisus maculiventris* (Say)
spiny oakworm ..... *Anisota stigma* (F.)
spirea aphid ..... *Aphis spiraecola* Patch
spotted asparagus beetle ..... *Crioceris duodecimpunctata* (L.)
spotted beet webworm ..... *Hymenia perspectalis* (Hbn.)
spotted blister beetle ..... *Epicauta maculata* (Say)
spotted cucumber beetle ..... *Diabrotica duodecimpunctata* (F.)
spotted cutworm ..... *Amathes c-nigrum* (L.)
spotted pine sawyer ..... *Monochamus maculosus* (Hald.)
spotted tussock moth ..... *Halisidota maculata* (Harr.)
spotted-winged antlion ..... *Dendroleon obsoletus* (Say)
spring cankerworm ..... *Paleacrita vernata* (Peck)
spruce aphid ..... *Aphis abietina* Wlkr.
spruce budworm ..... *Archips fumiferana* (Clem.)
spruce coneworm ..... *Dioryctria reniculella* (Grote)
spruce needle miner ..... *Taniva albolineana* (Kearf.)
spruce spider mite ..... *Paratetranychus ununguis* (Jac.)
square-necked grain beetle ..... *Cathartus quadricollis* (Guér.)
squash beetle ..... *Epilachna borealis* (F.)
squash borer ..... *Melittia cucurbitae* (Harr.)
squash bug ..... *Anasa tristis* (Deg.)
stable fly ..... *Stomoxys calcitrans* (L.)
stalk borer ..... *Papaipema nebris* (Guen.)
steel-blue lady beetle ..... *Orcus chalybeus* (Bdvl.)
sticktight flea ..... *Echidnophaga gallinacea* (Westw.)
stinging rose caterpillar. *Parasa indetermina* (Bdvl.)
stink beetle ..... *Nomius pygmaeus* (Dej.)
straw itch mite ..... *Pediculoides ventricosus* Newp.
strawberry aphid ..... *Capitophorus fragaefolii* (Ckll.)
strawberry crown borer. *Tyloderma fragariae* (Riley)
strawberry crown moth ..... *Ramosia bibionipennis* (Bdvl.)
strawberry leaf roller ..... *Ancylis comptana fragariae* (W. & R.)
strawberry root aphid ..... *Aphis forbesi* Weed
strawberry root weevil ..... *Brachyrhinus ovatus* (L.)
strawberry spider mite ..... *Tetranychus atlanticus* McG.
strawberry weevil ..... *Anthonomus signatus* Say
strawberry whitefly. *Trialeurodes packardi* (Morrill)
striped alder sawfly ..... *Hemichroa crocea* (Fourc.)
striped blister beetle ..... *Epicauta vittata* (F.)
striped cucumber beetle ..... *Diabrotica vittata* (F.)
striped cutworm ..... *Euxoa tessellata* (Harr.)
striped flea beetle ..... *Phyllotreta vittata* (F.)
striped garden caterpillar ..... *Polia legitima* (Grote)
striped horse fly ..... *Tabanus lineola* F.
suckfly ..... *Dicyphus minimus* Uhl.
sugar-beet root aphid ..... *Pemphigus betae* Doane
sugar-beet wireworm ..... *Limonius californicus* Mann.
sugar-maple borer ..... *Glycobius speciosus* (Say)
sugar-pine cone beetle ..... *Conophthorus lambertianae* Hopk
sugarcane beetle ..... *Euetheola rugiceps* (Lec.)
sugarcane borer ..... *Diatraea saccharalis* (F.)
sugarcane leaf roller ..... *Omiodes accepta* (Butl.)
sugarcane leafhopper ..... *Perkinsiella saccharicida* Kirk.
sunflower beetle ..... *Zygogramma exclamationis* (F.)
sunflower maggot ..... *Strauzia longipennis* (Wied.)
sunflower moth ..... *Homoeosoma electellum* (Hulst)
Surinam roach ..... *Pycnoscelus surinamensis* (L.)
swallow bug ..... *Oeciacus vicarius* Horv.
sweetclover weevil ..... *Sitona cylindricollis* Fahr.
sweetpotato flea beetle. *Chaetocnema confinis* Crotch
sweetpotato hornworm ..... *Herse cingulata* (F.)
sweetpotato leaf beetle ..... *Typophorus viridicyaneus* (Crotch)
sweetpotato leaf miner ..... *Bedellia orchilella* Wlsm.
sweetpotato leaf roller ..... *Pilocrocis tripunctata* (F.)
sweetpotato vine borer ..... *Omphisa anastomosalis* (Guen.)
sweetpotato weevil ..... *Cylas formicarius elegantulus* (Sum.)
sweetpotato whitefly ..... *Bemisia inconspicua* (Quaint.)
sycamore lace bug ..... *Corythucha ciliata* (Say)
sycamore tussock moth ..... *Halisidota harrisii* Walsh

Tahitian coconut weevil ..... *Diocalandra taitensis* (Guér.)

tarnished plant bug.....*Lygus oblineatus* (Say)
ten-lined June beetle.....
.....*Polyphylla decemlineata* (Say)
terrapin scale.....*Lecanium nigrofasciatum* Perg.
Texas leaf-cutting ant.....*Atta texana* Buckl.
thief ant.....*Solenopsis molesta* (Say)
thistle aphid.....*Anuraphis cardui* (L.)
three-banded leafhopper.....
.....*Erythroneura tricincta* Fitch
three-cornered alfalfa hopper.....
.....*Stictocephala festina* (Say)
three-lined potato beetle....*Lema trilineata* (Oliv.)
three-striped blister beetle.*Epicauta lemniscata* (F.)
throat bot fly.....*Gasterophilus nasalis* (L.)
thurberia weevil.....
.....*Anthonomus grandis thurberiae* Pierce
tiger swallowtail.....*Papilio glaucus* L.
tile-horned prionus.....*Prionus imbricornis* (L.)
toad bug.....*Gelastocoris oculatus* (F.)
tobacco budworm.....*Heliothis virescens* (F.)
tobacco flea beetle.....*Epitrix hirtipennis* Melsh.
tobacco hornworm.....*Protoparce sexta* (Johan.)
tobacco moth.....*Ephestia elutella* (Hbn.)
tobacco stalk borer.....*Trichobaris mucorea* (Lec.)
tobacco thrips.....*Frankliniella fusca* (Hinds)
tobacco wireworm.....*Conoderus vespertinus* (F.)
tomato fruitworm.....*Heliothis armigera* (Hbn.)
tomato hornworm.....
.....*Protoparce quinquemaculata* (Haw.)
tomato pinworm....*Keiferia lycopersicella* (Busck)
tomato psyllid.....*Paratrioza cockerelli* (Sulc)
tomato russet mite.....*Vasates destructor* (Keif.)
toothed flea beetle....*Chaetocnema denticulata* (Ill.)
tropical fowl mite.....*Liponyssus bursa* (Berl.)
tropical horse tick.....*Dermacentor nitens* Neum.
tropical rat mite.....*Liponyssus bacoti* (Hirst)
tuber flea beetle.....*Epitrix tuberis* Gent.
tule beetle.....*Agonum maculicolle* Dej.
tulip bulb aphid.....*Anuraphis tulipae* (Fonsc.)
tuliptree aphid...*Macrosiphum liriodendri* (Monell)
tuliptree scale.....*Toumeyella liriodendri* (Gmel.)
tupelo leaf miner.....*Antispila nyssaefoliella* Clem.
turkey gnat.....*Simulium meridionale* Riley
turnip aphid.....
.....*Rhopalosiphum pseudobrassicae* (Davis)
turnip maggot.....*Hylemya floralis* (Fall.)
twice-stabbed lady beetle...*Chilocoris stigma* (Say)
twig girdler.....*Oncideres cingulatus* (Say)
twig pruner.....*Hypermallus villosus* (F.)
two-lined chestnut borer..*Agrilus bilineatus* (Web.)
two-marked treehopper...*Enchenopa binotata* (Say)
two-spotted lady beetle.....*Adalia bipunctata* (L.)
two-spotted spider mite.....
.....*Tetranychus bimaculatus* Harvey
two-striped grasshopper.....
.....*Melanoplus bivittatus* (Say)
two-striped walkingstick.....
.....*Anisomorpha buprestoides* (Stoll)

ugly-nest caterpillar...*Archips cerasivorana* (Fitch)
unicorn caterpillar....*Schizura unicornis* (A. & S.)

vagabond crambus....*Crambus vulgivagellus* Clem.
variable oak leaf caterpillar.....
.....*Heterocampa manteo* (Dbldy.)
varied carpet beetle.....*Anthrenus verbasci* (L.)
variegated cutworm.....
.....*Peridroma margaritosa* (Haw.)
vedalia.....*Rodolia cardinalis* (Muls.)
vegetable weevil.....*Listroderes obliquus* Klug
velvetbean caterpillar.....
.....*Anticarsia gemmatilis* (Hbn.)
verbena bud moth.....*Endothenia hebesana* (Wlkr.)
vetch bruchid.....*Bruchus brachialis* Fahr.
viceroy.....*Basilarchia archippus* (Cram.)
violet aphid.....*Micromyzus violae* (Perg.)
violet sawfly.....*Ametastegia pallipes* (Spin.)
Virginia-creeper sphinx..*Ampeloeca myron* (Cram.)

w-marked cutworm....*Spaelotis clandestina* (Harr.)
walkingstick.....*Diapheromera femorata* (Say)
walnut aphid.....*Chromaphis juglandicola* (Kltb.)
walnut blister mite.....*Aceria erinea* (Nal.)
walnut caterpillar.....*Datana integerrima* G. & R.
walnut husk fly.....*Rhagoletis completa* Cress.
walnut scale.....*Aspidiotus juglans-regiae* Comst.
walnut sphinx.....*Cressonia juglandis* (A. & S.)
watercress leaf beetle...*Phaedon aeruginosus* Suffr.
watercress sowbug..*Mancasellus brachyurus* Harger
waterlily aphid.....*Rhopalosiphum nymphaeae* (L.)
waterlily leaf beetle.....*Galerucella nymphaeae* (L.)
waterlily leaf cutter...*Nymphula obliteralis* (Wlkr.)
wax moth.....*Galleria mellonella* (L.)
webbing clothes moth...*Tineola bisselliella* (Hum.)
West Indian cane weevil.....
.....*Metamasius hemipterus* (L.)
West Indian fruit fly.....
.....*Anastrepha mombinpraeoptans* Sein
West Indian sweetpotato weevil.....
.....*Euscepes postfasciatus* (Fairm.)
western balsam bark beetle.....
.....*Dryocoetes confusus* Swaine
western black flea beetle...*Phyllotreta pusilla* Horn
western cedar borer....*Trachykele blondeli* Marseul
western chicken flea.....*Ceratophyllus niger* Fox
western chinch bug.....*Blissus occiduus* Barber
western field wireworm..*Limonius infuscatus* Mots.
western grape rootworm.....*Adoxus obscurus* (L.)
western grape skeletonizer.....
.....*Harrisina brillians* B. & McD.
western harvester ant.....
.....*Pogonomyrmex occidentalis* (Cress.)
western peach tree borer.....
.....*Sanninoidea exitiosa graefi* (Hy. Edw.)
western pine beetle....*Dendroctonus brevicomis* Lec.
western potato flea beetle..*Epitrix subcrinita* (Lec.)
western raspberry fruitworm.*Byturus bakeri* Barber
western spotted cucumber beetle.....
.....*Diabrotica undecimpunctata* Mann.
western striped cucumber beetle.....
.....*Diabrotica trivittata* (Mann.)
western striped flea beetle.....
.....*Phyllotreta ramosa* (Crotch)
western tent caterpillar.....
.....*Malacosoma pluviale* (Dyar)
western thatching ant.....
.....*Formica rufa obscuripes* Forel
western tree-hole mosquito.....
.....*Aedes varipalpus* (Coq.)
western tussock moth.*Hemerocampa vetusta* (Bdvl.)
wharf borer.....*Nacerda melanura* (L.)
wheat head armyworm.....
.....*Protoleucania albilinea* (Hbn.)
wheat jointworm.....*Harmolita tritici* (Fitch)
wheat midge.....*Sitodiplosis mosellana* (Gehin)
wheat stem maggot.....*Meromyza americana* Fitch
wheat stem sawfly.....*Cephus cinctus* Nort.
wheat straw-worm.....*Harmolita grandis* (Riley)
wheat wireworm.....*Agriotes mancus* (Say)
wheel bug.....*Arilus cristatus* (L.)
white apple leafhopper...*Typhlocyba pomaria* McA.
white cutworm.....*Euxoa scandens* (Riley)
white-fringed beetle...*Pantomorus leucoloma* (Boh.)
white-lined sphinx.....*Celerio lineata* (F.)

white-marked spider beetle.....*Ptinus fur* L.
white-marked tussock moth.....
.....*Hemerocampa leucostigma* (A. & S.)
white peach scale.*Pseudaulacaspis pentagona* (Targ.)
white-pine aphid.....*Cinara strobi* (Fitch)
white-pine cone beetle.....
.....*Conophthorus coniperda* (Schw.)
white-pine sawfly.....*Neodiprion pinetum* (Nort.)
white-pine weevil.....*Pissodes strobi* (Peck)
white-spotted sawyer.*Monochamus scutellatus* (Say)
willow flea weevil.....*Rhynchaenus rufipes* (Lec.)
willow sawfly.....*Nematus ventralis* Say
willow shoot sawfly.....*Janus abbreviatus* (Say)
wing louse.....*Lipeurus caponis* (L.)
winter tick.....*Dermacentor albipictus* (Pack.)
woolly alder aphid...*Prociphilus tessellatus* (Fitch)
woolly apple aphid...*Eriosoma lanigerum* (Hausm.)
woolly elm aphid....*Eriosoma americanum* (Riley)
woolly pear aphid.....*Eriosoma pyricola* Baker
woolly whitefly.....*Aleurothrixus floccosus* (Mask.)
yellow-fever mosquito.....*Aedes aegypti* (L.)
yellow-headed cutworm.....*Septis arctica* (Freyer)
yellow-headed fireworm.....*Acleris minuta* (Rob.)
yellow-headed leafhopper.....
.....*Carneocephala flaviceps* (Riley)
yellow-headed spruce sawfly.....
.....*Pikonema alaskensis* (Roh.)
yellow mealworm.....*Tenebrio molitor* L.
yellow-necked caterpillar..*Datana ministra* (Drury)
yellow scale.....*Aonidiella citrina* (Coq.)
yellow-striped armyworm.....
.....*Prodenia ornithogalli* Guen.
yellow woollybear.....*Diacrisia virginica* (F.)
Yosemite bark weevil.....*Pissodes yosemite* Hopk.
yucca moth.....*Tegeticula yuccasella* (Riley)
yucca plant bug.....*Halticotoma valida* Reut.

zebra caterpillar.....*Ceramica picta* (Harr.)
Zimmerman pine moth.....
.....*Diroyctria zimmermani* (Grote)

COMMON NAMES OF INSECTS

II. INSECTS LISTED BY SCIENTIFIC NAMES

Abacarus hystrix (Nal.).....grain rust mite
Acantholyda erythrocephala (L.).pine false webworm
Acanthoscelides obtectus (Say).....bean weevil
Acarus siro L.....grain mite
Aceratagallia sanguinolenta (Prov.).....
.....clover leafhopper
Aceria caryae (Keif.).....pecan leafroll mite
Aceria erinea (Nal.).....walnut blister mite
Aceria essigi (Hassan).....redberry mite
Aceria ficus (Cotte).....fig mite
Aceria sheldoni (Ewing).....citrus bud mite
Aceria vaccinii (Keif.).....blueberry bud mite
Achatodes zeae (Harr.).....elder shoot borer
Acheta assimilis F.....field cricket
Acheta domestica L.....house cricket
Achroia grisella (F.).....lesser wax moth
Acleris minuta (Rob.).....yellow-headed fireworm
Acleris variana (Fern.).....black-headed budworm
Acrobasis caryae Grote.....pecan nut casebearer
Acrobasis juglandis (LeB.)....pecan leaf casebearer
Acronycta americana Harr...American dagger moth
Acronycta lepusculina Guen.....
.....cottonwood dagger moth
Acronycta oblinita (A. & S.)..smeared dagger moth
Acrosternum hilare (Say).....green stink bug
Actebia fennica (Tausch.).....black army cutworm
Adalia bipunctata (L.).....two-spotted lady beetle
Adelphocoris lineolatus (Goeze)....alfalfa plant bug
Adelphocoris rapidus (Say).....rapid plant bug
Adoxus obscurus (L.).....western grape rootworm
Aedes aboriginis Dyar....northwest coast mosquito
Aedes aegypti (L.).....yellow-fever mosquito
Aedes cantator (Coq.)...brown salt-marsh mosquito
Aedes lateralis (Meig.).....
.....northwestern floodwater mosquito
Aedes sollicitans (Wlkr.).....salt-marsh mosquito
Aedes squamiger (Coq.).....
.....California salt-marsh mosquito
Aedes sticticus (Meig.).....floodwater mosquito
Aedes varipalpus (Coq.).....
.....western tree-hole mosquito
Aegeria apiformis (Clerck).....hornet moth
Agasphaerops nigra Horn.....lily weevil
Agonoderus lecontei Chaud.....seed-corn beetle
Agonum maculicolle Dej.....tule beetle
Agrilus anxius Gory.....bronze birch borer
Agrilus bilineatus (Web.)..two-lined chestnut borer
Agrilus communis var. *rubicola* Abeille.....
.....rose stem girdler
Agrilus ruficollis (F.).....red-necked cane borer
Agrilus sinuatus (Oliv.).....sinuate pear tree borer
Agriotes mancus (Say).....wheat wireworm
Agromyza lantanae Frog.....lantana seed fly
Agromyza parvicornis Loew..corn blotch leaf miner
Agrotis malefida Guen.....pale-sided cutworm
Agrotis orthogonia Morr.....pale western cutworm
Agrotis ypsilon (Rott.).....black cutworm
Alabama argillacea (Hbn.).....cotton leafworm
Alaus oculatus (L.).....eyed click beetle
Aleurocanthus woglumi Ashby.....citrus blackfly
Aleurothrixus floccosus (Mask.).....woolly whitefly
Aleyrodes azaleae B. & M.....azalea whitefly
Allantus cinctus (L.).....curled rose sawfly
Alniphagus aspericollis (Lec.).....alder bark beetle
Alphitobius diaperinus (Panz.)....lesser mealworm
Alsophila pometaria (Harr.).....fall cankerworm
Altica ambiens (Lec.).....alder flea beetle
Altica canadensis (Gent.).....prairie flea beetle
Altica chalybea (Ill.).....grape flea beetle
Alypia octomaculata (F.).....eight-spotted forester
Amathes c-nigrum (L.).....spotted cutworm
Amblyomma americanum (L.).....lone star tick
Amblyomma cajennense (F.).....Cayenne tick
Amblyomma maculatum Koch.....Gulf Coast tick
Ametastegia glabrata (Fall.).....dock sawfly
Ametastegia pallipes (Spin.).....violet sawfly
Ampeloeca myron (Cram.)..Virginia-creeper sphinx
Ampeloglypter sesostris (Lec.).....
.....grape cane gall maker
Amphicerus hamatus (F.).....apple twig borer
Amphidasis cognataria Guen..pepper and salt moth
Anabrus simplex Hald.....Mormon cricket
Anagrapha falcifera (Kby.).....celery looper
Anaphothrips obscurus (Müll.).....grass thrips
Anarsia lineatella Zell.....peach twig borer
Anasa armigera (Say).....horned squash bug
Anasa tristris (Deg.).....squash bug
Anastrepha ludens (Loew).....Mexican fruit fly
Anastrepha mombinpraeoptans Sein.....
.....West Indian fruit fly

Anaticola crassicornis (Scop.)....slender duck louse
Anavitrinella pampinaria (Guen.).....cranberry spanworm
Ancylis comptana fragariae (W. & R.).....strawberry leaf roller
Anisomorpha buprestoides (Stoll).....two-striped walkingstick
Anisota rubicunda (F.)...green-striped mapleworm
Anisota senatoria (A. & S.).....orange-striped oakworm
Anisota stigma (F.).....spiny oakworm
Anomala oblivia Horn.....pine chafer
Anomala orientalis Waterh.....oriental beetle
Anopheles quadrimaculatus Say.....common malaria mosquito
Anthonomus eugenii Cano.....pepper weevil
Anthonomus grandis Boh.....boll weevil
Anthonomus grandis thurberiae Pierce.....thurberia weevil
Anthonomus musculus Say.....cranberry weevil
Anthonomus scutellaris Lec.....plum gouger
Anthonomus signatus Say.....strawberry weevil
Anthophila pariana (Clerck).....apple and thorn skeletonizer
Anthrenus scrophulariae (L.).....carpet beetle
Anthrenus verbasci (L.).....varied carpet beetle
Anthrenus vorax (Waterh.)...furniture carpet beetle
Anticarsia gemmatilis (Hbn.)..velvetbean caterpillar
Antispila nyssaefoliella Clem.....tupelo leaf miner
Antonina graminis (Mask.).....Rhodes-grass scale
Anuraphis bakeri (Cowen).....clover aphid
Anuraphis cardui (L.).....thistle aphid
Anuraphis maidi-radicis (Forbes)...corn root aphid
Anuraphis persicae-niger (Smith).....black peach aphid
Anuraphis roseus Baker.....rosy apple aphid
Anuraphis tulipae (Fonsc.).....tulip bulb aphid
Anuraphis viburnicola (Gill.).....snowball aphid
Aonidiella aurantii (Mask.).....California red scale
Aonidiella citrina (Coq.).....yellow scale
Aphis abietina Wlkr.....spruce aphid
Aphis fabae Scop.....bean aphid
Aphis forbesi Weed.....strawberry root aphid
Aphis gossypii Glov.....cotton aphid, melon aphid
Aphis hederae Kltb.....ivy aphid
Aphis illinoisensis Shimer.....grapevine aphid
Aphis maidis Fitch.....corn leaf aphid
Aphis medicaginis Koch.....cowpea aphid
Aphis pomi Deg.....apple aphid
Aphis spiraecola Patch.....spirea aphid
Aphrophora parallela (Say).....pine spittlebug
Aphrophora saratogensis (Fitch).....Saratoga spittlebug
Apis mellifera L.....honey bee
Araecerus fasciculatus (Deg.).....coffee bean weevil
Archips argyrospila (Wlkr.).....fruit tree leaf roller
Archips cerasivorana (Fitch)...ugly-nest caterpillar
Archips conflictana (Wlkr.).....large aspen tortrix
Archips fumiferana (Clem.).....spruce budworm
Archips rosaceana (Harr.).....oblique-banded leaf roller
Argas persicus (Oken).....fowl tick
Argyresthia conjugella Zell.....apple fruit moth
Argyresthia thuiella (Pack.)...arborvitae leaf miner
Argyrotaenia citrana (Fern.).....orange tortrix
Argyrotaenia juglandana (Fern.)..hickory leaf roller
Argyrotaenia mariana (Fern.).....gray-banded leaf roller
Argyrotaenia pinatubana (Kearf.)...pine tube moth
Argyrotaenia velutinana (Wlkr.).....red-banded leaf roller
Arilus cristatus (L.).....wheel bug

Arrhenodes minutus (Drury).....oak timberworm
Asarcopus palmarum Horv.....datebug
Asphondylia websteri Felt.....alfalfa gall midge
Aspidiotus ancylus (Putn.).....Putnam scale
Aspidiotus britannicus Newst.....holly scale
Aspidiotus californicus Clmn...black pine leaf scale
Aspidiotus camelliae Sign.....greedy scale
Aspidiotus destructor Sign.....coconut scale
Aspidiotus forbesi Johns.....Forbes scale
Aspidiotus hederae (Vallot).....oleander scale
Aspidiotus howardi Ckll.....Howard scale
Aspidiotus ithacae (Ferris).....hemlock scale
Aspidiotus juglans-regiae Comst.....walnut scale
Aspidiotus ostreaeformis Curt..European fruit scale
Aspidiotus perniciosus Comst.....San Jose scale
Aspidiotus uvae Comst.....grape scale
Atta texana Buckl.....Texas leaf-cutting ant
Attagenus piceus (Oliv.).....black carpet beetle
Atteva aurea (Fitch).....alianthus webworm
Aulacaspis rosae (Bouché).....rose scale
Autographa californica (Speyer).....alfalfa looper
Automeris io (F.).....io moth
Autoplusia egena (Guen.)....bean leaf skeletonizer
Autoserica castanea (Arrow)...Asiatic garden beetle

Barathra configurata (Wlkr.).....bertha armyworm
Basilarchia archippus (Cram.).....viceroy
Battus philenor (L.).....pipevine swallowtail
Bedellia orchilella Wlsm.....sweetpotato leaf miner
Bedellia somnulentella (Zell.).....morning-glory leaf miner
Bembecia marginata (Harr.)...raspberry root borer
Bemisia inconspicua (Quaint.).sweetpotato whitefly
Blatta orientalis L.....oriental cockroach
Blatella germanica (L.).....German cockroach
Blennocampa rubi (Harr.).....raspberry sawfly
Blissus hirtus Montd.....hairy chinch bug
Blissus leucopterus (Say).....chinch bug
Blissus occiduus Barber.....western chinch bug
Bombyx mori (L.).....silkworm
Boophilus annulatus (Say).....cattle tick
Bourletiella hortensis (Fitch).....garden springtail
Bovicola bovis (L.).....cattle biting louse
Bovicola equi (L.).....horse biting louse
Brachyrhinus ligustici (L.).....alfalfa snout beetle
Brachyrhinus ovatus (L.)....strawberry root weevil
Brachyrhinus sulcatus (F.).....black vine weevil
Brachystola magna (Gir.).....lubber grasshopper
Bregmatothrips iridis Watson.....iris thrips
Brevicoryne brassicae (L.).....cabbage aphid
Bruchophagus gibbus (Boh.).....clover seed chalcid
Bruchus brachialis Fahr.....vetch bruchid
Bruchus pisorum (L.).....pea weevil
Bruchus rufimanus Boh.....broadbean weevil
Bryobia praetiosa Koch.....clover mite
Bucculatrix ainsliella Murtf.....oak skeletonizer
Bucculatrix canadensisella Chamb. birch skeletonizer
Bucculatrix thurberiella Busck.....cotton leaf perforator
Byturus bakeri Barber..western raspberry fruitworm
Byturus rubi Barber...eastern raspberry fruitworm

Caenurgina erechtea (Cram.).....forage looper
Calendra aequalis (Gyll.).....clay-colored billbug
Calendra maidis (Chitt.).....maize billbug
Caliroa cerasi (L.).....pear-slug
Calladonus clitellarius (Say).....saddled leafhopper
Calligrapha scalaris (Lec.).....elm calligrapha
Callitroga americana (C. & P.).....screw-worm
Callitroga macellaria (F.)....secondary screw-worm
Callopistria floridensis (Guen.).....Florida fern caterpillar

Callosamia promethea (Drury).....promethea moth
Callosobruchus maculatus (F.).....cowpea weevil
Calosoma calidum (F.).....fiery hunter
Calpodes ethlius (Stoll).....larger canna leaf roller
Cameraria cincinnatiella (Chamb.).....gregarious oak leaf miner
Cameraria hamadryadella (Clem.).....solitary oak leaf miner
Camnula pellucida Scudd..clear-winged grasshopper
Camponotus abdominalis floridanus (Buckl.).....Florida carpenter ant
Camponotus herculeanus pennsylvanicus (Deg.)....black carpenter ant
Camponotus herculeanus pennsylvanicus ferrugineus (F.).....red carpenter ant
Capitophorus fragaefolii (Ckll.)...strawberry aphid
Capitophorus ribis (L.).....currant aphid
Carneocephala flaviceps (Riley).....yellow-headed leafhopper
Carpocapsa pomonella (L.).....codling moth
Carpoglyphus lactis (L.).....dried-fruit mite
Carpophilus dimidiatus (F.).....corn sap beetle
Carpophilus hemipterus.....dried-fruit beetle
Cathartus quadricollis (Guér.).....square-necked grain beetle
Caulocampus acericaulis (MacG.).....maple petiole borer
Caulophilus latinasus (Say).....broad-nosed grain weevil
Cecidophyes gossypii (Banks)....cotton blister mite
Cecidophyes ribis (Nal.).....currant bud mite
Celama sorghiella (Riley).....sorghum webworm
Celerio lineata (F.).....white-lined sphinx
Cephus cinctus Nort.....wheat stem sawfly
Cephus pygmaeus (L.).European wheat stem sawfly
Cephus tabidus (F.).....black grain stem sawfly
Ceramica picta (Harr.).....zebra caterpillar
Ceratitis capitata (Wied.)...Mediterranean fruit fly
Ceratomia catalpae (Bdvl.).....catalpa sphinx
Ceratophyllus gallinae (Schr.).....European chicken flea
Ceratophyllus niger Fox.....western chicken flea
Ceresa bubalus (F.).....buffalo treehopper
Ceroplastes cirripediformis Comst.....barnacle scale
Ceroplastes floridensis Comst.....Florida wax scale
Cerotoma trifurcata (Forst.).....bean leaf beetle
Ceutorhynchus assimilis (Payk.).....cabbage seedpod weevil
Ceutorhynchus quadridens (Panz.).....cabbage seedstalk curculio
Ceutorhynchus rapae Gyll.....cabbage curculio
Chaetocnema confinis Crotch.....sweetpotato flea beetle
Chaetocnema denticulata (Ill.)....toothed flea beetle
Chaetocnema ectypa Horn....desert corn flea beetle
Chaetocnema pulicaria Melsh.....corn flea beetle
Chalcodermus aeneus Boh.....cowpea curculio
Chalepus dorsalis Thunb.....locust leaf miner
Chaoborus astictopus D. & S.....Clear Lake gnat
Chelymorpha cassidea (F.).....argus tortoise beetle
Chermes abietis L.....eastern spruce gall aphid
Chermes cooleyi Gill.....Cooley spruce gall aphid
Chilo plejadellus Zinck.....rice stalk borer
Chilo simplex (Butl.).....Asiatic rice borer
Chilocoris stigma (Say)...twice-stabbed lady beetle
Chion cinctus (Drury).....banded hickory borer
Chionaspis americana Johns.....elm scurfy scale
Chionaspis corni Cooley.....dogwood scale
Chionaspis furfura (Fitch).....scurfy scale
Chlamydatus associatus (Uhl.)...ragweed plant bug
Chlorochroa ligata (Say).....conchuela
Chlorochroa sayi Stål.....Say stink bug
Chorizagrotis auxiliaris (Grote).....army cutworm
Chromaphis juglandicola (Kltb.).....walnut aphid
Chrysobothris femorata (Oliv.).....flatheaded apple tree borer
Chrysobothris mali Horn....Pacific flatheaded borer
Chrysobothris tranquebarica (Gmel.).....Australian-pine borer
Chrysomela scripta F.....cottonwood leaf beetle
Chrysomela tremulae F.....aspen leaf beetle
Chrysomphalus aonidum (L.).....Florida red scale
Chrysomphalus dictyospermi (Morg.).....dictyospermum scale
Chrysomphalus obscurus (Comst.).....obscure scale
Chrysomphalus tenebricosus (Comst.)..gloomy scale
Chrysopa oculata Say.....golden-eye lacewing
Conophthorus coniperda (Schw.).....white-pine cone beetle
Cimbex americana Leach.....elm sawfly
Cimex lectularius L.....bed bug
Cinara strobi (Fitch).....white-pine aphid
Cingilia catenaria (Drury)..chain-spotted geometer
Cirphis unipuncta (Haw.).....armyworm
Citheronia regalis (F.).....hickory horned devil, regal moth
Cladius isomerus Nort.....bristly rose-slug
Clastoptera proteus Fitch.....dogwood spittlebug
Clytoleptus albofasciatus (C. & G.).....grape trunk borer
Cnemidocoptes gallinae (Raill.).....depluming mite
Cnemidocoptes mutans (R. & L.).....scaly-leg mite
Cnephasia longana (Haw.).....omnivorous leaf tier
Cnidocampa flavescens (Wlkr.).....oriental moth
Coccus hesperidum L.....soft scale
Coccus pseudomagnoliarum (Kuw.)...citricola scale
Coccus viridis (Green).....green scale
Colaspis flavida (Say).....grape colaspis
Coleophora caryaefoliella Clem.....pecan cigar casebearer
Coleophora fletcherella Fern.....cigar casebearer
Coleophora laricella (Hbn.).....larch casebearer
Coleophora limosipennella (Dup.)....elm casebearer
Coleophora malivorella Riley.....pistol casebearer
Coleophora pruniella Clem.....cherry casebearer
Coleophora salmani Heinr.....birch casebearer
Colias philodice eurytheme Bdvl...alfalfa caterpillar
Colias philodice philodice Latr.....clouded sulphur
Colopha ulmicola (Fitch).....elm cockscomb gall
Coloradia pandora Blake.....pandora moth
Columbicola columbae (L.).....slender pigeon louse
Conoderus vespertinus (F.).....tobacco wireworm
Conophthorus contortae Hopk.....lodgepole cone beetle
Conophthorus edulis Hopk.....piñon cone beetle
Conophthorus lambertianae Hopk.....sugar-pine cone beetle
Conophthorus ponderosae Hopk.....ponderosa-pine cone beetle
Conophthorus radiatae Hopk.....Monterey-pine cone beetle
Conophthorus resinosae Hopk.....red-pine cone beetle
Conotrachelus crataegi Walsh.....quince curculio
Conotrachelus nenuphar (Hbst.).....plum curculio
Contarinia johnsoni (Sling.)....grape blossom midge
Contarinia pyrivora (Riley).....pear midge
Contarinia sorghicola (Coq.).....sorghum midge
Coptodisca splendoriferella (Clem.).....resplendent shield bearer
Corimelaena pulicaria (Germ.).....negro bug
Corthylus columbianus Hopk.....Columbian timber beetle
Cortophaga viridifasciata (Deg.).....green meadow locust
Corydalus cornutus (L.)....dobsonfly, hellgrammite

Corythucha celtidis O. & D. hackberry lace bug
Corythucha ciliata (Say) sycamore lace bug
Corythucha cydoniae (Fitch) hawthorn lace bug
Corythucha gossypii (F.) cotton lace bug
Corythucha marmorata (Uhl.) chrysanthemum lace bug
Corythucha ulmi O. & D. elm lace bug
Cosmopolites sordidus (Germ.) banana root borer
Cossula magnifica (Stkr.) pecan carpenterworm
Cotinis nitida (L.) green June beetle
Crambus caliginosellus Clem. corn root webworm
Crambus teterrellus (Zinck.) bluegrass webworm
Crambus topiarius Zell. cranberry girdler
Crambus vulgivagellus Clem. vagabond crambus
Craponius inaequalis (Say) grape curculio
Cremastobombycia lantanella Busck lantana leaf miner
Cressonia juglandis (A. & S.) walnut sphinx
Crioceris asparagi (L.) asparagus beetle
Crioceris duodecimpunctata (L.) spotted asparagus beetle
Croesus latitarsus Nort. dusky birch sawfly
Crymodes devastator (Brace) glassy cutworm
Cryptococcus fagi (Baer.) beech scale
Cryptophlebia illepida (Butl.) koa seedworm
Cryptorhynchus lapathi (L.) poplar and willow borer
Cryptorhynchus mangiferae (F.) mango weevil
Ctenicera aereipennis aereipennis (Kby.) Puget Sound wireworm
Ctenicera aereipennis destructor (Brown) prairie grain wireworm
Ctenocephalides canis (Curt.) dog flea
Ctenocephalides felis (Bouché) cat flea
Cuclotogaster heterographus (Nitz.) chicken head louse
Culex pipiens L. northern house mosquito
Culex quinquefasciatus Say southern house mosquito
Curculio auriger (Casey) chestnut weevil
Curculio caryae (Horn) pecan weevil
Curculio proboscideus F. large chestnut weevil
Curculio uniformis (Lec.) filbert weevil
Cylas formicarius elegantulus (Sum.) sweetpotato weevil

Dactylopius coccus Costa cochineal insect
Dacus cucurbitae (Coq.) melon fly
Dacus oleae (Gmel.) olive fruit fly
Danaus plexippus (L.) monarch butterfly
Dasyneura leguminicola (Lint.) clover seed midge
Dasyneura rhodophaga (Coq.) rose midge
Dasyneura trifolii (Loew) clover leaf midge
Datana integerrima G. & R. walnut caterpillar
Datana ministra (Drury) yellow-necked caterpillar
Deinocerites cancer Theob. crab-hole mosquito
Deloyala guttata (Oliv.) mottled tortoise beetle
Demodex bovis Stiles cattle follicle mite
Demodex canis Leydig dog follicle mite
Demodex canis var. *ovis* Raill. sheep follicle mite
Demodex caprae Raill. goat follicle mite
Demodex cati Megn. cat follicle mite
Demodex equi Raill. horse follicle mite
Demodex phylloides Csokor hog follicle mite
Dendroctonus approximatus Dietz. Colorado pine beetle
Dendroctonus arizonicus Hopk. Arizona pine beetle
Dendroctonus barberi Hopk. southwestern pine beetle
Dendroctonus borealis Hopk. Alaska spruce beetle
Dendroctonus brevicomis Lec. western pine beetle
Dendroctonus convexifrons Hopk. roundheaded pine beetle
Dendroctonus engelmanni Hopk. Engelmann spruce beetle
Dendroctonus frontalis Zimm. southern pine beetle
Dendroctonus jeffreyi Hopk. Jeffrey pine beetle
Dendroctonus mexicanus Hopk. smaller Mexican pine beetle
Dendroctonus micans (Kug.) European spruce beetle
Dendroctonus monticolae Hopk. mountain pine beetle
Dendroctonus murrayanae Hopk. lodgepole-pine beetle
Dendroctonus obesus (Mann.) Sitka-spruce beetle
Dendroctonus parallelocollis Chap. larger Mexican pine beetle
Dendroctonus piceaperda Hopk. eastern spruce beetle
Dendroctonus ponderosae Hopk. Black Hills beetle
Dendroctonus pseudotsugae Hopk. Douglas-fir beetle
Dendroctonus punctatus Lec. Allegheny spruce beetle
Dendroctonus rufipennis (Kby.) red-winged pine beetle
Dendroctonus simplex Lec. eastern larch beetle
Dendroctonus terebrans (Oliv.) black turpentine beetle
Dendroctonus valens Lec. red turpentine beetle
Dendroleon obsoletus (Say) spotted-winged antlion
Depressaria heracliana (L.) parsnip webworm
Dermacentor albipictus (Pack.) winter tick
Dermacentor andersoni Stiles Rocky Mountain wood tick
Dermacentor nitens Neum. tropical horse tick
Dermacentor occidentalis Neum. Pacific Coast tick
Dermacentor variabilis (Say) American dog tick
Dermanyssus gallinae (Deg.) chicken mite
Dermatobia hominis (L., Jr.) human bot fly
Dermestes ater Deg. black larder beetle
Dermestes lardarius L. larder beetle
Dermestes maculatus Deg. hide beetle
Derocrepis erythropus (Melsh.) red-legged flea beetle
Desmia funeralis (Hbn.) grape leaf folder
Diabrotica balteata Lec. banded cucumber beetle
Diabrotica duodecimpunctata (F.) southern corn rootworm, spotted cucumber beetle
Diabrotica longicornis (Say) corn rootworm
Diabrotica trivittata (Mann.) western striped cucumber beetle
Diabrotica undecimpunctata Mann. western spotted cucumber beetle
Diabrotica vittata (F.) striped cucumber beetle
Diacrisia virginica (F.) yellow woollybear
Dialeurodes chittendeni Laing rhododendron whitefly
Dialeurodes citri (Ashm.) citrus whitefly
Dialeurodes citrifolii (Morg.) cloudy-winged whitefly
Diaphania hyalinata (L.) melonworm
Diaphania nitidalis (Stoll) pickleworm
Diapheromera femorata (Say) walkingstick
Diarthronomyia hypogaea (Loew) chrysanthemum gall midge
Diaspis bromeliae (Kern.) pineapple scale
Diaspis carueli Targ. juniper scale
Diaspis echinocacti (Bouché) cactus scale
Diatraea crambidoides (Grote) southern cornstalk borer
Diatraea grandiosella Dyar. southwestern corn borer
Diatraea saccharalis (F.) sugarcane borer
Dichelonyx backi (Kby.) green rose chafer
Dichomeris ligulella Hbn. palmerworm

Dichomeris marginella (F.).....juniper webworm
Dicyphus minimus Uhl.....suckfly
Diocalandra taitensis (Guér.).....
.....Tahitian coconut weevil
Dioryctria reniculella (Grote).....spruce coneworm
Dioryctria zimmermani (Grote).....
.....Zimmerman pine moth
Diplolepis radicum (O. S.).....rose root gall
Diplolepis rosae (L.).....mossy rose gall
Diprion hercyniae (Htg.)...European spruce sawfly
Diprion simile (Htg.).....introduced pine sawfly
Disonycha xanthomelaena (Dalm.).....
.....spinach flea beetle
Dissosteira carolina (L.).....Carolina grasshopper
Dorymyrmex pyramicus (Roger).....pyramid ant
Dryocoetes confusus Swaine.....
.....western balsam bark beetle
Dysdercus mimulus Hussey..Arizona cotton stainer
Dysdercus suturellus (H. S.).....cotton stainer

Eacles imperialis (Drury).....imperial moth
Ecdytolopha insiticiana Zell.....locust twig borer
Echidnophaga gallinacea (Westw.)....sticktight flea
Elasmopalpus lignosellus (Zell.).....
.....lesser cornstalk borer
Fleodes opaca (Say).....plains false wireworm
Empoasca fabae (Harr.).....potato leafhopper
Empoasca maligna (Walsh).....apple leafhopper
Enchenopa binotata (Say)...two-marked treehopper
Endelomyia aethiops (F.).....rose-slug
Endothenia hebesana (Wlkr.)....verbena bud moth
Ennomos subsignarius (Hbn.).....elm spanworm
Entomoscelis americana Brown....red turnip beetle
Eomenacanthus stramineus (Nitz.).....
.....chicken body louse
Ephestia cautella (Wlkr.).....almond moth
Ephestia elutella (Hbn.).....tobacco moth
Ephestia figulilella Greg.....raisin moth
Ephestia kühniella Zell...Mediterranean flour moth
Epiblema otiosana (Clem.).....bidens borer
Epiblema strenuana (Wlkr.).....ragweed borer
Epicaerus imbricatus (Say).....
.....imbricated snout beetle
Epicauta cinerea (Forst.).....gray blister beetle
Epicauta fabricii (Lec.).....ash-gray blister beetle
Epicauta lemniscata (F.).....
.....three-striped blister beetle
Epicauta maculata (Say).....spotted blister beetle
Epicauta pennsylvanica (Deg.)..black blister beetle
Epicauta solani Werner.....margined blister beetle
Epicauta vittata (F.).....striped blister beetle
Epicnaptera americana (Harr.).....lappet moth
Epidiaspis piricola (Del Guer.)..Italian pear scale
Epilachna borealis (F.).....squash beetle
Epilachna varivestis Muls.....Mexican bean beetle
Epinotia aceriella (Clem.).....
.....maple trumpet skeletonizer
Epitrimerus pyri (Nal.).....pear rust mite
Epitrix cucumeris (Harr.).....potato flea beetle
Epitrix fuscula Crotch.....eggplant flea beetle
Epitrix hirtipennis Melsh.....tobacco flea beetle
Epitrix subcrinita (Lec.)..western potato flea beetle
Epitrix tuberis Gent.....tuber flea beetle
Epochra canadensis Loew.....currant fruit fly
Erannis tiliaria (Harr.).....linden looper
Eriococcus azaleae Comst.....azalea bark scale
Eriophyes pyri (Pgst.).....pear leaf blister mite
Eriophyes vitis (Pgst.).....grape erineum mite
Eriosoma americanum (Riley)....woolly elm aphid
Eriosoma lanigerum (Hausm.)...woolly apple aphid
Eriosoma pyricola Baker.....woolly pear aphid
Erynephala puncticollis (Say).....beet leaf beetle
Erythraspides pygmaea (Say).....grape sawfly
Erythroneura tricincta Fitch.....
.....three-banded leafhopper
Estigmene acrea (Drury).....salt-marsh caterpillar
Etiella zinckenella (Treit.).....lima-bean pod borer
Euborellia annulipes (Lucas).....ring-legged earwig
Euetheola rugiceps (Lec.).....sugarcane beetle
Eumerus tuberculatus Rond.....lesser bulb fly
Euphoria inda (L.).....bumble flower beetle
Eurytoma orchidearum (Westw.).....orchidfly
Euscepes postfasciatus (Fairm.).....
.....West Indian sweetpotato weevil
Eusimulium pecuarum (Riley).....
.....southern buffalo gnat
Eutettix tenellus (Baker).....beet leafhopper
Eutrombicula alfreddugèsi (Oud.).....chigger
Euxoa messoria (Harr.).....dark-sided cutworm
Euxoa ochrogaster (Guen.).....red-backed cutworm
Euxoa scandens (Riley).....white cutworm
Euxoa tessellata (Harr.).....striped cutworm
Euzophera semifuneralis (Wlkr.).....
.....American plum borer
Evergestis rimosalis (Guen.).....
.....cross-striped cabbageworm
Evoxysoma vitis (Saund.).....grape seed chalcid
Exartema permundanum Clem.....
.....raspberry leaf roller
Exoteleia pinifoliella (Chamb.).....
.....pine needle miner

Fannia canicularis (L.).....little house fly
Fannia scalaris (F.).....latrine fly
Felicola subrostrata (Nitz.).....cat louse
Feltia subgothica (Haw.).....dingy cutworm
Feltia subterranea (F.).....granulate cutworm
Fenusa dohrnii (Tisch.)..European alder leaf miner
Fenusa pusilla (Klug).....birch leaf miner
Fenusa ulmi Sund.....elm leaf miner
Fidia viticida Walsh.....grape rootworm
Forficula auricularia L.....European earwig
Formica exsectoides Forel....Allegheny mound ant
Formica fusca var. *subsericea* Say.....silky ant
Formica rufa obscuripes Forel.....
.....western thatching ant
Frankliniella fusca (Hinds).....tobacco thrips
Frankliniella tritici (Fitch).....flower thrips
Fundella pellucens Zell.....Caribbean pod borer

Galeruca browni Blake.....peppergrass beetle
Galerucella cavicollis (Lec.).....cherry leaf beetle
Galerucella nymphaeae (L.).....waterlily leaf beetle
Galerucella xanthomelaena (Schr.)....elm leaf beetle
Galleria mellonella (L.).....wax moth
Gargaphia solani Heid.....eggplant lace bug
Gargaphia tiliae (Walsh).....basswood lace bug
Gasterophilus haemorrhoidalis (L.).....nose bot fly
Gasterophilus intestinalis (Deg.).....horse bot fly
Gasterophilus nasalis (L.).....throat bot fly
Gelastocoris oculatus (F.).....toad bug
Gliricola porcelli (L.).....slender guinea-pig louse
Glossonotus crataegi (Fitch).....quince treehopper
Glycobius speciosus (Say).....sugar-maple borer
Gnathocerus cornutus (F.).....
.....broad-horned flour beetle
Gnorimoschema operculella (Zell.).....
.....potato tuberworm
Goes tesselatus (Hald.).....oak sapling borer
Goniocotes bidentatus Scop.....small pigeon louse
Goniocotes hologaster Nitz.....fluff louse
Goniodes dissimilis Nitz.....brown chicken louse
Goniodes gigas (Tasch.).....large chicken louse
Gossyparia spuria (Mod.).....European elm scale

Gracilaria azaleella Brants.....azalea leaf miner
Gracilaria cuculipennella (Hbn.)...privet leaf miner
Gracilaria negundella Chamb....boxelder leaf roller
Gracilaria syringella (F.).....lilac leaf miner
Grapholitha interstinctana (Clem.).....
.....clover head caterpillar
Grapholitha molesta (Busck).....oriental fruit moth
Grapholitha packardi Zell.....cherry fruitworm
Grapholitha prunivora (Walsh)....lesser appleworm
Gretchena bolliana (Sling.).....pecan bud moth
Gryllotalpa hexadactyla Perty.....
.....northern mole cricket
Gynaikothrips ficorum (March.).....
.....Cuban-laurel thrips

Haemaphysalis chordeilis Pack.....bird tick
Haemaphysalis leporis-palustris Pack....rabbit tick
Haematopinus adventicius Neum.....hog louse
Haematopinus asini (L.).....horse sucking louse
Haematopinus eurysternus (Nitz.).....
.....short-nosed cattle louse
Haematosiphon inodorus (Dugès).....poultry bug
Haemodipsus ventricosus (Denny).....rabbit louse
Halisidota caryae (Harr.).....hickory tussock moth
Halisidota harrisii Walsh...sycamore tussock moth
Halisidota maculata (Harr.)...spotted tussock moth
Halisidota tessellaris (A. & S.)...pale tussock moth
Halticotoma valida Reut.....yucca plant bug
Halticus bracteatus (Say).....garden fleahopper
Harmolita grandis (Riley).....wheat straw-worm
Harmolita tritici (Fitch).....wheat jointworm
Harpipteryx xylostella (L.).....
.....European honeysuckle leaf roller
Harrisina americana (Guér.).....
.....grape leaf skeletonizer
Harrisina brillians B. & McD.....
.....western grape skeletonizer
Hedia variegana (Hbn.).....green budworm
Heliothis armigera (Hbn.).....
.....bollworm, corn earworm, tomato fruitworm
Heliothis ononis (Schiff.).....flax bollworm
Heliothis virescens (F.).....tobacco budworm
Heliothrips haemorrhoidalis (Bouché).....
.....greenhouse thrips
Hellula undalis (F.).....cabbage webworm
Hemerocampa leucostigma (A. & S.).....
.....white-marked tussock moth
Hemerocampa pseudotsugata McD.....
.....Douglas-fir tussock moth
Hemerocampa vetusta (Bdvl.).....
.....western tussock moth
Hemichroa crocea (Fourc.).....striped alder sawfly
Hemileuca maia (Drury).....buck moth
Hemileuca oliviae Ckll.....range caterpillar
Hemitarsonemus latus (Banks).....broad mite
Hercinothrips femoralis (Reut.).....
.....banded greenhouse thrips
Hercothrips fasciatus (Perg.).....bean thrips
Herse cingulata (F.).....sweetpotato hornworm
Heterocampa guttivitta (Wlkr.)...saddled prominent
Heterocampa manteo (Dbldy.).....
.....variable oak leaf caterpillar
Heteroderes laurentii (Guér.).....Gulf wireworm
Hippodamia convergens Guér.....
.....convergent lady beetle
Homadaula albizziae Clarke.....mimosa webworm
Homaledra sabalella (Chamb.).....
.....palm leaf skeletonizer
Homoeosoma electellum (Hulst).....sunflower moth
Hoplocampa cookei (Clarke).....cherry fruit sawfly
Hoplocampa testudinea (Klug).....
.....European apple sawfly

Horistonotus uhlerii Horn.....sand wireworm
Howardia biclavis (Comst.).....mining scale
Hyalopterus arundinis (F.).....mealy plum aphid
Hydroecia micacea (Esp.).....potato stem borer
Hylastinus obscurus (Marsh.).....clover root borer
Hylecoetus lugubris Say.....sapwood timberworm
Hylemya abdena Hall.....carnation tip maggot
Hylemya antiqua (Meig.).....onion maggot
Hylemya brassicae (Bouché).....cabbage maggot
Hylemya brunnescens (Zett.).....carnation maggot
Hylemya cilicrura (Rond.).....seed-corn maggot
Hylemya floralis (Fall.).....turnip maggot
Hylobius pales (Hbst.).....pales weevil
Hylobius radicis Buch.....pine root collar weevil
Hylotrupes bajulus (L.).....old house borer
Hylurgopinus rufipes (Eichh.).....
.....native elm bark beetle
Hymenia perspectalis (Hbn.).....
.....spotted beet webworm
Hymenia recurvalis (F.)..Hawaiian beet webworm
Hypena humuli (Harr.).....hop looper
Hypera nigrirostris (F.)....lesser clover leaf weevil
Hypera postica (Gyll.).....alfalfa weevil
Hypera punctata (F.).....clover leaf weevil
Hypermallus villosus (F.).....twig pruner
Hyphantria cunea (Drury).....fall webworm
Hypoderma bovis (Deg.).....northern cattle grub
Hypoderma lineatum (De Vill.).....
.....common cattle grub
Hyponomeuta padella (L.).....ermine moth
Hypothenemus hispidulus (Lec.).....
.....apple twig beetle
Hypsopygia costalis (F.).....clover hayworm
Hysteroneura setariae (Thos.).....rusty plum aphid

Icerya purchasi Mask.....cottony-cushion scale
Ichthyura inclusa Hbn.....poplar tent maker
Ips pini (Say).....pine engraver
Iridomyrmex humilis Mayr.....Argentine ant
Ischnaspis longirostris (Sign.)....black thread scale
Isia isabella (A. & S.).....banded woollybear
Itame ribearia (Fitch).....currant spanworm
Ithycerus noveboracensis (Forst.)..New York weevil
Itonida catalpae (Comst.).....catalpa midge
Ixodes scapularis Say.....black-legged tick

Janus abbrevictus (Say).....willow shoot sawfly
Janus integer (Nort.).....currant stem girdler
Jonthonota nigripes (Oliv.).....
.....black-legged tortoise beetle

Kakimia houghtonensis (Troop).....
.....gooseberry witchbroom aphid
Keiferia glochinella (Zell.).....eggplant leaf miner
Keiferia lycopersicella (Busck)....tomato pinworm

Labopidea allii Kngt.....onion plant bug
Lacinipolia renigera (Steph.).....bristly cutworm
Laemophloeus ferrugineus (Steph.).....
.....rusty grain beetle
Laemophloeus minutus (Oliv.).....flat grain beetle
Lambdina fiscellaria (Guen.).....hemlock looper
Lampetia equestris (F.).....narcissus bulb fly
Languria mozardi Latr.....clover stem borer
Laphygma exempta (Wlkr.)....nutgrass armyworm
Laphygma exigua (Hbn.).....beet armyworm
Laphygma frugiperda (A. & S.).....fall webworm
Lasioderma serricorne (F.).....cigarette beetle
Lasius claviger (Roger).....smaller yellow ant
Lasius interjectus Mayr.....larger yellow ant
Lasius niger alienus americanus Emery.....
.....cornfield ant

Laspeyresia caryana (Fitch)....hickory shuckworm
Laspeyresia nigricana (Steph.).....pea moth
Latrodectus mactans (F.).....black widow spider
Lecanium cerasorum Ckll.....calico scale
Lecanium corni Bouché...European fruit lecanium
Lecanium nigrofasciatum Perg.....terrapin scale
Lecanium persicae (F.).....European peach scale
Lecanium prunastri (Fonsc.).....globose scale
Lema trilineata (Oliv.)....three-lined potato beetle
Lepidosaphes beckii (Newm.).....purple scale
Lepidosaphes camelliae Hoke.....camellia scale
Lepidosaphes ficus (Sign.).....fig scale
Lepidosaphes gloverii (Pack.).....Glover scale
Lepidosaphes ulmi (L.).....oystershell scale
Lepisma saccharina L.....silverfish
Leptinotarsa decemlineata (Say) .....Colorado potato beetle
Leptinotarsa juncta (Germ.).....false potato beetle
Leptocoris trivittatus (Say).....boxelder bug
Leptoglossus phyllopus (L.).....leaf-footed bug
Lethocerus americanus (Leidy).....giant water bug
Ligyrus gibbosus (Deg.).....carrot beetle
Limonius agonus (Say).....eastern field wireworm
Limonius californicus Mann...sugar-beet wireworm
Limonius canus Lec.....Pacific Coast wireworm
Limonius infuscatus Mots...western field wireworm
Limonius subauratus Lec.....Columbia Basin wireworm
Limothrips cerealium Hal.....grain thrips
Linognathus vituli (L.).....long-nosed cattle louse
Liothrips floridensis (Watson).....camphor thrips
Liothrips vaneeckei Pries.....lily bulb thrips
Lipeurus caponis (L.).....wing louse
Liponyssus bacoti (Hirst).....tropical rat mite
Liponyssus bursa (Berl.).....tropical fowl mite
Liponyssus silviarum (C. & F.)..northern fowl mite
Liposcelis divinatorius (Müll.).....booklouse
Liriomyza pusilla (Meig.).....serpentine leaf miner
Lissorhoptrus simplex (Say).....rice water weevil
Listroderes obliquus Klug.....vegetable weevil
Listronotus oregonensis (Lec.).....carrot weevil
Lithophane antennata (Wlkr.).....green fruitworm
Lixus concavus Say.....rhubarb curculio
Lopidea dakota Kngt.....caragana plant bug
Lopidea davisi Kngt.....phlox plant bug
Loxostege commixtalis (Wlkr.).....alfalfa webworm
Loxostege similalis (Guen.).....garden webworm
Loxostege sticticalis (L.).....beet webworm
Lucanus elaphus F.....giant stag beetle
Ludius inflatus (Say).....dry-land wireworm
Ludius pruininus noxius (Hyslop) .....Great Basin wireworm
Luperodes brunneus (Crotch).....corn silk beetle
Lyctus planicollis Lec.....southern lyctus beetle
Lygaeus kalmii Stål.....small milkweed bug
Lygidea mendax Reut.....apple red bug
Lygris diversilineata (Hbn.).....grapevine looper
Lygus oblineatus (Say).....tarnished plant bug
Lytta nuttalli Say.....Nuttall blister beetle
Lytta vesicatoria (L.).....Spanish-fly

Macrodactylus subspinosus (F.).....rose chafer
Macronoctua onusta Grote.....iris borer
Macropsis trimaculata (Fitch).....plum leafhopper
Macrosiphoniella sanborni (Gill.) .....chrysanthemum aphid
Macrosiphum granarium (Kby.) .....English grain aphid
Macrosiphum lilii (Monell) .....purple-spotted lily aphid
Macrosiphum liriodendri (Monell)...tuliptree aphid
Macrosiphum pisi (Kltb.).....pea aphid
Macrosiphum rosae (L.).....rose aphid
Macrosiphum rudbeckiae (Fitch)..goldenglow aphid
Macrosiphum solanifolii (Ashm.).....potato aphid
Macrosteles divisus (Uhl.)....six-spotted leafhopper
Magdalis aenescens Lec....bronze apple tree weevil
Magdalis armicollis (Say).....red elm bark weevil
Magdalis barbita (Say).....black elm bark weevil
Magicicada septendecim (L.).....periodical cicada
Malacosoma americanum (F.) .....eastern tent caterpillar
Malacosoma californicum (Pack.) .....California tent caterpillar
Malacosoma disstria Hbn. .....forest tent caterpillar
Malacosoma pluviale (Dyar) .....western tent caterpillar
Mancasellus brachyurus Harger..watercress sowbug
Mantis religiosa L.....European mantis
Marmara elotella (Busck).....apple bark miner
Marmara pomonella Busck.....apple fruit miner
Megacyllene caryae (Gahan)..painted hickory borer
Megacyllene robiniae (Forst.).....locust borer
Megalopyge crispata (Pack.)..crinkled flannel moth
Megalopyge opercularis (A. & S.)....püss caterpillar
Melanagromyza simplex (Loew)....asparagus miner
Melanocallis caryaefoliae (Davis) .....black pecan aphid
Melanophila consputa Lec.....charcoal beetle
Melanophila drummondi (Kby.) .....flatheaded fir borer
Melanophila fulvoguttata (Harr.).....hemlock borer
Melanoplus bivittatus (Say) .....two-striped grasshopper
Melanoplus differentialis (Thos.) .....differential grasshopper
Melanoplus femur-rubrum (Deg.) .....red-legged grasshopper
Melanoplus mexicanus devastator Scudd. .....devastating grasshopper
Melanoplus mexicanus mexicanus (Sauss.) .....lesser migratory grasshopper
Melanoplus mexicanus spretus (Walsh) .....Rocky Mountain grasshopper
Melanoplus packardii Scudd...Packard grasshopper
Melanotrichus althaeae (Hussey) .....hollyhock plant bug
Melanotus oregonensis (Lec.).....Oregon wireworm
Melissopus latiferreanus (Wlsm.).....filbertworm
Melitara dentata (Grote).....blue cactus borer
Melittia cucurbitae (Harr.).....squash borer
Melittomma sericeum (Harr.)..chestnut timberworm
Melophagus ovinus (L.).....sheep-tick
Menopon gallinae (L.).....shaft louse
Meromyza americana Fitch.....wheat stem maggot
Metamasius hemipterus (L.) .....West Indian cane weevil
Metamasius ritchiei Mshl.....pineapple weevil
Metamasius sericeus (Oliv.).....silky cane weevil
Metriona bicolor (F.).....golden tortoise beetle
Microcentrum retinerve (Burm.) .....angular-winged katydid
Microcentrum rhombifolium (Sauss.) .....broad-winged katydid
Micromyzus violae (Perg.).....violet aphid
Mindarus abietinus Koch.....balsam twig aphid
Mineola indigenella (Zell.).....leaf crumpler
Mineola vaccinii (Riley).....cranberry fruitworm
Miris dolabratus (L.).....meadow plant bug
Monarthropalpus buxi Laboulb. .....boxwood leaf miner
Monellia costalis (Fitch).....black-margined aphid
Monocesta coryli (Say).....larger elm leaf beetle

Monochamus maculosus (Hald.) ..... spotted pine sawyer
Monochamus marmorator (Kby.) .. balsam-fir sawyer
Monochamus notatus (Drury) .. northeastern sawyer
Monochamus oregonensis (Lec.) ... Oregon fir sawyer
Monochamus scutellatus (Say) ..... white-spotted sawyer
Monochamus titillator (F.) .... southern pine sawyer
Monomorium minimum (Buckl.) .... little black ant
Monomorium pharaonis (L.) ..... Pharaoh ant
Mononychus vulpeculus (F.) ..... iris weevil
Monoptilota pergratialis (Hulst) ..... lima-bean vine borer
Mordwilkoja vagabunda (Walsh) ..... poplar vagabond aphid
Murgantia histrionica (Hahn) ..... harlequin bug
Musca domestica L. ..... house fly
Musca vicina Macq. ..... oriental house fly
Muscina stabulans (Fall.) ..... false stable fly
Mycodiplosis alternata Felt ..... dogwood club-gall midge
Myelois venipars Dyar ..... navel orangeworm
Myzocallis kahawaluokalani Kirk. ..... crapemyrtle aphid
Myzocallis ulmifolii (Monell) ..... elm leaf aphid
Myzus cerasi (F.) ..... black cherry aphid
Myzus circumflexus (Buck.) ..... crescent-marked lily aphid
Myzus convolvuli (Kltb.) ..... foxglove aphid
Myzus ligustri (Mosley) ..... privet aphid
Myzus persicae (Sulz.) ..... green peach aphid

Nacerda melanura (L.) ..... wharf borer
Necrobia ruficollis (F.) ... red-shouldered ham beetle
Necrobia rufipes (Deg.) ..... red-legged ham beetle
Nemapogon granella (L.) ..... European grain moth
Nematocampa limbata (Haw.) ..... filament bearer
Nematus ribesii (Scop.) ..... imported currantworm
Nematus ventralis Say ..... willow sawfly
Neoborus amoenus (Reut.) ..... ash plant bug
Neoclytus acuminatus (F.) .... red-headed ash borer
Neodiprion abietis (Harr.) ..... balsam-fir sawfly
Neodiprion banksianae Roh. ..... jack-pine sawfly
Neodiprion burkei Midd. ..... lodgepole sawfly
Neodiprion lecontei (Fitch) .. red-headed pine sawfly
Neodiprion pinetum (Nort.) ..... white-pine sawfly
Neodiprion tsugae Midd. ..... hemlock sawfly
Neolecanium cornuparvum (Thro) .... magnolia scale
Neoheegeria verbasci (Osb.) ..... mullein thrips
Neolygus caryae Kngt. ..... hickory plant bug
Neolygus communis (Kngt.) ..... pear plant bug
Neophasia manapia (F. & F.) ..... pine butterfly
Nephelodes emmedonia (Cram.) ... bronzed cutworm
Nephopteryx rubrizonella Rag. ..... pear fruit borer
Nepticula gossypii F. & L. ..... cotton leaf miner
Neurotoma inconspicua (Nort.) ..... plum web-spinning sawfly
Nezara viridula (L.) ..... southern green stink bug
Nilotaspis halli (Green) ..... Hall scale
Niptus hololeucus (Fald.) ..... golden spider beetle
Nodonota punctticollis (Say) ..... rose leaf beetle
Nomius pygmaeus (Dej.) ..... stink beetle
Nosopsyllus fasciatus (Bosc) ..... rat flea
Notolophus antiqua (L.) ..... rusty tussock moth
Nygmia phaeorrhoea (Donov.) ..... brown-tail moth
Nymphalis antiopa (L.) ... mourning-cloak butterfly
Nymphula obliteralis (Wlkr.) ... waterlily leaf cutter
Nysius ericae (Schill.) ..... false chinch bug

Oberea bimaculata (Oliv.) ..... raspberry cane borer
Oberea tripunctata (Swed.) ..... dogwood twig borer
Oecanthus nigricornis nigricornis Wlkr. ..... black-horned tree cricket
Oecanthus nigricornis quadripunctatus Beut. ..... four-spotted tree cricket
Oecanthus niveus (Deg.) ..... snowy tree cricket
Oeciacus vicarius Horv. ..... swallow bug
Oestrus ovis L. ..... sheep bot fly
Oligia fractilinea (Grote) ..... lined stalk borer
Omiodes accepta (Butl.) ..... sugarcane leaf roller
Omiodes blackburni (Butl.) ..... coconut leaf roller
Omphisa anastomosalis (Guen.) ..... sweetpotato vine borer
Oncideres cingulata (Say) ..... twig girdler
Oncopeltus faciatus (Dall.) ..... large milkweed bug
Operophtera bruceata (Hulst) ..... Bruce spanworm
Ophiola vaccinii (Van D.) ..... blunt-nosed cranberry leafhopper
Orcus chalybeus (Bdvl.) ..... steel-blue lady beetle
Ornithodoros turicata (Dugès) ... relapsing-fever tick
Orthezia insignis Browne ..... greenhouse orthezia
Oryzaephilus surinamensis (L.) ..... saw-toothed grain beetle
Oscinella frit (L.) ..... frit fly
Otobius megnini (Dugès) ..... ear tick

Pachnaeus litus (Germar) ..... citrus root weevil
Pachynematus extensicornis (Nort.) .... grass sawfly
Pachypsylla celtidis-mamma (Flet.) ..... hackberry nipple gall
Pachyzancla bipunctalis (F.) ..... southern beet webworm
Paleacrita vernata (Peck) ..... spring cankerworm
Palorus subdepressus (Woll.) .. depressed flour beetle
Panchlora cubensis Sauss. ..... Cuban cockroach
Pantographa limata G. & R. .... basswood leaf roller
Pantomorus godmani (Crotch) .... Fuller rose beetle
Pantomorus leucoloma (Boh.) ... white-fringed beetle
Papaipema nebris (Guen.) ..... stalk borer
Papaipema purpurifascia (G. & R.) columbine borer
Papilio ajax L. ..... black swallowtail, celeryworm, parsleyworm
Papilio cresphontes Cram. ..... orange-dog
Papilio glaucus L. ..... tiger swallowtail
Papilio troilus L. ..... spice-bush swallowtail
Paracalocoris hawleyi Kngt. ..... hop plant bug
Paraclemensia acerifoliella (Fitch) ..... maple leaf cutter
Parasa indetermina (Bdvl.) .. stinging rose caterpillar
Paratetranychus citri (McG.) ..... citrus red mite
Paratetranychus ilicis (McG.) .... southern red mite
Paratetranychus pilosus (C. & F.) ..... European red mite
Paratetranychus simplex (Banks) ..... date mite
Paratetranychus ununguis (Jac.) ..... spruce spider mite
Paratetranychus yothersi (McG.) .. avocado red mite
Paratrechina longicornis (Latr.) ..... crazy ant
Paratrioza cockerelli (Sulc) ..... potato psyllid, tomato psyllid
Parlatoria blanchardi (Targ.) ... parlatoria date scale
Parlatoria chinensis Marl. .... Chinese obscure scale
Parlatoria oleae (Colvée) ..... olive scale
Parlatoria pergandii Comst. ..... chaff scale
Pectinophora gossypiella (Saund.) .... pink bollworm
Pediculoides ventricosus Newp. ..... straw itch mite
Pediculus humanus corporis Deg. ..... body louse
Pediculus humonus humanus L. ..... head louse
Pegomya hyoscyami (Panz.) ..... spinach leaf miner
Pegomya rubicora (Coq.) .... raspberry cane maggot
Pemphigus betae Doane ..... sugar-beet root aphid
Peranabrus scabricollis (Thos.) ..... coulee cricket
Peridroma margaritosa (Haw.) .. variegated cutworm

Periphyllus lyropictus (Kess.) ..... Norway-maple aphid
Periphyllus negundinis (Thos.) ..... boxelder aphid
Periplaneta americana (L.) .... American cockroach
Periplaneta australasiae (F.) .. Australian cockroach
Perkinsiella saccharicida Kirk. ..... sugarcane leafhopper
Petrova comstockiana (Fern.) ..... pitch twig moth
Phaedon aeruginosus Suffr. .... watercress leaf beetle
Pholacrus politus Melsh. ..... smut beetle
Phenacaspis pinifoliae (Fitch) ..... pine needle scale
Phenacoccus gossypii T. & C. .... Mexican mealybug
Philaenus leucophthalmus (L.) .. meadow spittlebug
Philaenus lineatus (L.) ..... lined spittlebug
Philosamia cynthia (Drury) ..... cynthia moth
Phlocotribus liminaris (Harr.) .... peach bark beetle
Phylctaenia rubigalis (Guen.) ..... celery leaf tier, greenhouse leaf tier
Phobetron pithecium (A. & S.) ..... hag moth
Phoenicococcus marlatti Ckll. ..... red date scale
Pholus achemon (Drury) ..... achemon sphinx
Phormia regina (Meig.) ..... black blow fly
Phorodon humuli (Schr.) ..... hop aphid
Phryganidia californica Pack. .. California oakworm
Phthirus pubis (L.) ..... crab louse
Phyllocoptes gracilis (Nal.) .... blackberry leaf mite
Phyllocoptruta oleivora (Ashm.) .... citrus rust mite
Phyllotreta armoraciae (Koch) ..... horseradish flea beetle
Phyllotreta pusilla Horn ... western black flea beetle
Phyllotreta ramosa (Crotch) ..... western striped flea beetle
Phyllotreta vittata (F.) ..... striped flea beetle
Phylloxera devastatrix Perg. ..... pecan phylloxera
Phylloxera notabilis Perg. ..... pecan leaf phylloxera
Phylloxera vitifoliae (Fitch) ..... grape phylloxera
Phytomyza chrysanthemi (Kowarz) ..... chrysanthemum leaf miner
Phytomyza delphiniae Frost ..... larkspur leaf miner
Phytomyza ilicis (Curt.) ..... holly leaf miner
Phytomyza minuscula Gour. .... columbine leaf miner
Phytophaga destructor (Say) ..... hessian fly
Phytoptus avellanae Nal. ..... filbert bud mite
Phytoptus pini Nal. ..... pine bud mite
Pieris protodice B. & L. ..... southern cabbageworm
Pieris rapae (L.) ..... imported cabbageworm
Pikonema alaskensis (Roh.) ..... yellow-headed spruce sawfly
Pikonema dimmocki (Cress.) ..... green-headed spruce sawfly
Pilocrocis tripunctata (F.) .... sweetpotato leaf roller
Pineus strobi (Htg.) ..... pine bark aphid
Pinnaspis aspidistrae (Sign.) ..... fern scale
Piophila casei (L.) ..... cheese skipper
Pissodes engelmanni Hopk. ..... Engelmann spruce weevil
Pissodes nemorensis Germ. ..... deodar weevil
Pissodes radiatae Hopk. ..... Monterey-pine weevil
Pissodes sitchensis Hopk. ..... Sitka-spruce weevil
Pissodes strobi (Peck) ..... white-pine weevil
Pissodes yosemite Hopk. ..... Yosemite bark weevil
Plagiodera versicolora (Laich.) ..... imported willow leaf beetle
Plathypena scabra (F.) ..... green cloverworm
Platyptilia carduidactyla (Riley) ..... artichoke plume moth
Platyptilia pusillodactyla (Wlkr.) ..... lantana plume moth
Plectrodera scalator (F.) ..... cottonwood borer
Plodia interpunctella (Hbn.) ..... Indian-meal moth
Plutella maculipennis (Curt.) ... diamondback moth
Pnyxia scabiei (Hopk.) ..... potato scab gnat
Podapion gallicola Riley ..... pine gall weevil
Podisus maculiventris (Say) ..... spined soldier bug
Podosesia syringae fraxini (Lug.) ..... ash borer
Podosesia syringae syringae (Harr.) ..... lilac borer
Poecilocapsus lineatus (F.) ..... four-lined plant bug
Pogonomyrmex badius (Latr.) ..... Florida harvester ant
Pogonomyrmex barbatus (F. Smith) ..... red harvester ant
Pogonomyrmex californicus (Buckl.) ..... California harvester ant
Pogonomyrmex occidentalis (Cress.) ..... western harvester ant
Polia legitima (Grote) .... striped garden caterpillar
Pollenia rudis (F.) ..... cluster fly
Polychrosis viteana (Clem.) ..... grape berry moth
Polyphylla decemlineata (Say) .. ten-lined June beetle
Pomphopoea sayi (Lec.) ..... Say blister beetle
Pontania bozemani Cooley ..... poplar leaf-folding sawfly
Popilius disjunctus (Ill.) ..... horned passalus
Popillia japonica Newm. ..... Japanese beetle
Porthetria dispar (L.) ..... gypsy moth
Prionoxystus macmurtrei (Guér.) ..... little carpenterworm
Prionoxystus robiniae (Peck) ..... carpenterworm
Prionus californicus Mots. ..... California prionus
Prionus imbricornis (L.) ..... tile-horned prionus
Prionus laticollis (Drury) .. broad-necked root borer
Pristiphora californica (Marl.) .. California pear-slug
Pristiphora erichsonii (Htg.) ..... larch sawfly
Pristiphora geniculata (Htg.) ... mountainash sawfly
Prociphilus imbricator (Fitch) ... beech blight aphid
Prociphilus tessellatus (Fitch) ... woolly alder aphid
Prodenia eridania (Cram.) ..... southern armyworm
Prodenia ornithogalli Guen. ..... yellow-striped armyworm
Proteides clarus (Cram.) ..... silver-spotted skipper
Proteoteras willingana (Kearf.) .. boxelder twig borer
Protoleucania albilinea (Hbn.) ..... wheat head armyworm
Protoparce quinquemaculata (Haw.) ..... tomato hornworm
Protoparce sexta (Johan.) ..... tobacco hornworm
Protopulvinaria pyriformis (Ckll.) ... pyriform scale
Psallus seriatus (Reut.) ..... cotton fleahopper
Pseudanthonomus validus Dietz ... currant fruit weevil
Pseudaonidia duplex (Ckll.) ..... camphor scale
Pseudaulacaspis pentagona (Targ.) ..... white peach scale
Pseudococcus adonidum (L.) ... long-tailed mealybug
Pseudococcus brevipes (Ckll.) ... pineapple mealybug
Pseudococcus citri (Risso) ..... citrus mealybug
Pseudococcus comstocki (Kuw.) .. Comstock mealybug
Pseudococcus gahani Green .... citrophilus mealybug
Pseudococcus maritimus (Ehrh.) .... grape mealybug
Pseudococcus nipae (Mask.) ..... coconut mealybug
Pseudodacus pallens (Coq.) ..... bumelia fruit fly
Pseudolynchia canariensis (Macq.) ..... pigeon fly
Psila rosae (F.) ..... carrot rust fly
Psoroptes equi Gerv. ..... scab mite
Psoroptes ovis (Her.) ..... sheep scab mite
Psorosina hammondi (Riley) . apple leaf skeletonizer
Psylla buxi (L.) ..... boxwood psyllid
Psylla mali (Schmdb.) ..... apple sucker
Psylla pyricola Foerst. ..... pear psylla
Psylliodes punctulata Melsh. ..... hop flea beetle
Pterophorus periscelidactylus Fitch ..... grape plume moth
Ptinus fur L. ..... white-marked spider beetle
Ptinus hirtellus Sturm ..... brown spider beetle
Ptinus villiger (Reit.) ..... hairy spider beetle

Pulex irritans L. human flea
Pulvinaria amygdali Ckll. cottony peach scale
Pulvinaria psidii Mask. green shield scale
Pulvinaria vitis (L.) cottony maple scale
Pycnoscelus surinamensis (L.) Surinam roach
Pyralis farinalis (L.) meal moth
Pyrausta ainsliei Heinr. smartweed borer
Pyrausta nubilalis (Hbn.) European corn borer

Ramosia bibionipennis (Bdvl.) strawberry crown moth
Ramosia rhododendri (Beut.) rhododendron borer
Ramosia tipuliformis (Clerck) currant borer
Recurvaria milleri Busck lodgepole needle miner
Recurvaria nanella (Hbn.) lesser bud moth
Reduvius personatus (L.) masked hunter
Rhabdopterus picipes (Oliv.) cranberry rootworm
Rhabdoscelus obscurus (Bdvl.) New Guinea sugarcane weevil
Rhagoletis cingulata (Loew) cherry fruit fly, cherry maggot
Rhagoletis completa Cress. walnut husk fly
Rhagoletis fausta (O. S.) black cherry fruit fly
Rhagoletis pomonella (Walsh) apple maggot, blueberry maggot
Rhipicephalus sanguineus (Latr.) brown dog tick
Rhizobius ventralis (Er.) black lady beetle
Rhizoecus terrestris (Newst.) ground mealybug
Rhizoglyphus echinopus (F. & R.) bulb mite
Rhopalosiphum nymphaeae (L.) waterlily aphid
Rhopalosiphum prunifoliae (Fitch) apple grain aphid
Rhopalosiphum pseudobrassicae (Davis) turnip aphid
Rhopobota naevana (Hbn.) black-headed fireworm
Rhyacionia buoliana (Schiff.) European pine shoot moth
Rhyacionia frustrana (Comst.) Nantucket pine moth
Rhynchaenus pallicornis (Say) apple flea weevil
Rhynchaenus rufipes (Lec.) willow flea weevil
Rhynchites bicolor (F.) rose curculio
Rhyzopertha dominica (F.) lesser grain borer
Rodolia cardinalis (Muls.) vedalia
Romalea microptera (Beauv.) eastern lubber grasshopper

Saissetia hemisphaerica (Targ.) hemispherical scale
Saissetia oleae (Bern.) black scale
Salebria subcaesiella (Clem.) locust leaf roller
Samia cecropia (L.) cecropia moth
Sannina uroceriformis Wlkr. persimmon borer
Sanninoidea exitiosa (Say) peach tree borer
Sanninoidea exitiosa graefi (Hy. Edw.) western peach tree borer
Saperda calcarata Say poplar borer
Saperda candida F. roundheaded apple tree borer
Saperda tridentata Oliv. elm borer
Saperda vestita Say linden borer
Sarcophaga kellyi Ald. grasshopper maggot
Sarcoptes scabiei (Deg.) itch mite
Scapteriscus acletus R. & H. southern mole cricket
Scapteriscus vicinus Scudd. changa
Schistocerca americana (Drury) American grasshopper
Schizura concinna (A. & S.) red-humped caterpillar
Schizura unicornis (A. & S.) unicorn caterpillar
Scirtothrips citri (Moult.) citrus thrips
Scobicia declivis (Lec.) lead cable borer
Scolytus multistriatus (Marsh.) smaller European elm bark beetle
Scolytus muticus Say hackberry engraver
Scolytus quadrispinosus Say hickory bark beetle
Scolytus rugulosus (Ratz.) shot-hole borer
Scolytus sulcatus Lec. larger shot-hole borer
Scolytus unispinosus Lec. Douglas-fir engraver
Scolytus ventralis Lec. fir engraver
Scotogramma trifolii (Rott.) clover cutworm
Scudderia furcata Brun. fork-tailed bush katydid
Scutigera cleoptrata (L.) house centipede
Scutigerella immaculata (Newp.) garden centipede
Selenothrips rubrocinctus (Giard) red-banded thrips
Semanotus ligneus (F.) cedar tree borer
Septis arctica (Freyer) yellow-headed cutworm
Sibine stimulea (Clem.) saddleback caterpillar
Similium meridionale Riley turkey gnat
Siphona irritans (L.) horn fly
Sirex juvencus (L.) blue horntail
Sitodiplosis mosellana (Gehin) wheat midge
Sitona cylindricollis Fahr. sweetclover weevil
Sitona hispidula (F.) clover root curculio
Sitona lineata (L.) pea leaf weevil
Sitophilus granarius (L.) granary weevil
Sitophilus oryza (L.) rice weevil
Sitotroga cerealella (Oliv.) Angoumois grain moth
Smicronyx sculpticollis Casey dodder gall weevil
Solenopsis geminata (F.) fire ant
Solenopsis molesta (Say) thief ant
Solenopsis xyloni McCook southern fire ant
Spaelotis clandestina (Harr.) w-marked cutworm
Spilonota ocellana (D. & S.) eye-spotted bud moth
Stagmomantis carolina (Johan.) Carolina mantis
Stegasta bosquella (Chamb.) red-necked peanutworm
Stegobium paniceum (L.) drug-store beetle
Stenopelmatus fuscus Hald. Jerusalem cricket
Stephanitis pyrioides Scott azalea lace bug
Stephanitis rhododendri Horv. rhododendron lace bug
Stictocephala festina (Say) three-cornered alfalfa hopper
Stilpnotia salicis (L.) satin moth
Stomoxys calcitrans (L.) stable fly
Strauzia longipennis (Wied.) sunflower maggot
Strymon melinus (Hbn.) cotton square borer
Supella supellectilium (Serv.) brown-banded roach
Sylvora acerni (Clem.) maple callus borer
Synanthedon pictipes (G. & R.) lesser peach tree borer
Systena blanda Melsh. pale-striped flea beetle
Systena elongata (F.) elongate flea beetle
Systoechus vulgaris Loew grasshopper bee fly

Tabanus atratus F. black horse fly
Tabanus lineola F. striped horse fly
Tachycines asynamorus Adel. greenhouse stone cricket
Tachypterellus quadrigibbus (Say) apple curculio
Taeniothrips inconsequens (Uzel) pear thrips
Taeniothrips simplex (Mor.) galdiolus thrips
Taniva albolineana (Kearf.) spruce needle miner
Tapinoma sessile (Say) odorous house ant
Tarsonemus laticeps Halb. bulb scale mite
Tarsonemus pallidus Banks cyclamen mite
Tegeticula yuccasella (Riley) yucca moth
Telea polyphemus (Cram.) polyphemus moth
Teleonemia lantanae Dist. lantana lace bug
Tenebrio molitor L. yellow mealworm
Tenebrio obscurus F. dark mealworm
Tenebroides mauritanicus (L.) cadelle
Tenodera angustipennis Sauss. narrow-winged mantis
Tenodera aridifolia sinensis Sauss. Chinese mantis

Tethida cordigera (Beauv.)..black-headed ash sawfly
Tetraleurodes mori (Quaint.).....mulberry whitefly
Tetralopha robustella Zell.....pine webworm
Tetralopha scortealis (Led.).....lespedeza webworm
Tetramorium caespitum (L.).....pavement ant
Tetranychus atlanticus McG.....
.....strawberry spider mite
Tetranychus bimaculatus Harvey.....
.....two-spotted spider mite
Tetranychus pacificus McG.....Pacific mite
Tetranychus sexmaculatus Riley....six-spotted mite
Tetraopes tetrophthalmus (Forst.).....
.....red milkweed beetle
Tetropium abietis Fall.....roundheaded fir borer
Thamnosphecia pyri (Harr.).....pear borer
Thamnosphecia scitula (Harr.).....dogwood borer
Thermobia domestica (Pack.).....firebrat
Thrips nigropilosus Uzel....chrysanthemum thrips
Thrips tabaci Lind.....onion thrips
Thyridopteryx ephemeraeformis (Haw.)....bagworm
Tinea pellionella (L.).....casemaking clothes moth
Tineola bisselliella (Hum.)...webbing clothes moth
Tipula simplex Doane.....range crane fly
Tischeria malifoliella Clem.....
.....apple leaf trumpet miner
Tomostethus multicinctus (Roh.).....
.....brown-headed ash sawfly
Torymus druparum Boh.....apple seed chalcid
Toumeyella liriodendri (Gmel.).....tuliptree scale
Toumeyella numismaticum (P. & M.).....
.....pine tortoise scale
Toxoptera aurantii (Fonsc.).....black citrus aphid
Toxoptera graminum (Rond.).....greenbug
Toxotrypana curricauda Gerst.....papaya fruit fly
Trachykele blondeli Marseul....western cedar borer
Tremex columba (L.).....pigeon tremex
Trialeurodes floridensis (Quaint.)..avocado whitefly
Trialeurodes packardi (Morrill)..strawberry whitefly
Trialeurodes vaporariorum (Westw.).....
.....greenhouse whitefly
Trialeurodes vittatus (Quaint.).....grape whitefly
Triatoma sanguisuga (Lec.)..bloodsucking conenose
Tribolium castaneum (Hbst.).....red flour beetle
Tribolium confusum Duv.....confused flour beetle
Trichobaris mucorea (Lec.).....tobacco stalk borer
Trichobaris trinotata (Say).....potato stalk borer
Trichophaga tapetzella (L.).....carpet moth
Trichoplusiani (Hbn.).....cabbage looper
Trinoton querquedulae (L.).....large duck louse
Trioza diospyri (Ashm.).....persimmon psylla
Tropaea luna (L.).....luna moth
Tunga penetrans (L.).....chigoe
Tychius griseus Schaeff.....clover head weevil
Tyloderma fragariae (Riley).....
.....strawberry crown borer
Typhlocyba pomaria McA...white apple leafhopper
Typhlocyba rosae (L.).....rose leafhopper
Typophorus viridicyaneus (Crotch).....
.....sweetpotato leaf beetle
Tyrophagus lintneri (Osb.).....mushroom mite

Unaspis euonymi (Comst.).....euonymus scale
Urbanus proteus (L.).....bean leaf roller
Utetheisa bella (L.).....bella moth

Vanessa atalanta (L.).....red-admiral
Vanessa cardui (L.).....painted-lady
Vanessa virginiensis (Drury).....painted beauty
Vasates cornutus (Banks).....peach silver mite
Vasates destructor (Keif.).....tomato russet mite
Vasates quadripedes Shimer.....
.....maple bladder-gall mite
Vasates schlechtendali (Nal.).....apple rust mite
Vespa crabro germana Christ.....giant hornet
Vespamima pini (Kell.).....pitch mass borer
Vespamima sequoiae (Hy. Edw.).....
.....sequoia pitch moth
Vespula maculata (L.).....bald-faced hornet
Virgula meleagridis (L.).....large turkey louse
Vitacea polistiformis (Harr.).....grape root borer
Vitula serratilineella Rag.....dried-fruit moth

Wasmannia auropunctata (Roger).....little fire ant
Wyeomyia smithii (Coq.)....pitcherplant mosquito

Xenopsylla cheopis (Rothsch.).....oriental rat flea
Xylocopa virginica (Drury).....carpenter bee
Xylotrechus aceris Fisher.....
.....gall-making maple borer
Xylotrechus colonus (F.).....rustic borer

Zaraea inflata Nort.....honeysuckle sawfly
Zeuzera pyrina (L.).....leopard moth
Zophodia convolutella (Hbn.)..gooseberry fruitworm
Zygogramma exclamationis (F.)....sunflower beetle

The Insecticide Situation

F. C. Bishopp, *Bureau of Entomology and Plant Quarantine, Agr. Res. Adm., U.S.D.A.*

At the beginning of the war the insect situation was complicated by real or threatened shortages of some of our most dependable ammunition for fighting insect infestations. First, copper needed in the manufacture of paris green and copper sulfate became critical because of war demands. Then the diversion of arsenic supplies to prepare to meet possible poison gas attacks became necessary. Following this German U-boats began to interfere seriously with the shipment to this country from Kenya of our old stand-by, pyrethrum. Soon after Pearl Harbor, when the Japanese invaded Malaya and the East Indies, they took over our major source of rotenone. Substitutes became the order of the day, and the entomologist, the chemist, the manufacturer, and the consumer were never quite sure when a suggested substitute might become critical.

To meet this urgent situation scientists reviewed the records of earlier experiments. Numerous materials that had been tried in the process of finding the most effective or safest ones for various uses were given further consideration. The long-since outmoded soaps, kerosene emulsions, and tobacco decoctions were resurrected and in some instances put to use. The United States Department of Agriculture issued bulletins listing substitutes for scarce or critical materials and giving formulas designed to make such materials go farther. Research was initiated to determine the minimum quantities of scarce materials that would give satisfactory control of various pests and to find cultural or mechanical means of reducing insect depredations with a lessened use of insecticides. Search for new insecticidal materials and new sources of existing materials was pressed forward, and work on activating or extending agents was accelerated. In this effort federal and state agencies were joined by many private individuals and industrial groups. Crops of most value in the prosecution of the war were given priorities in the allocation of insect-killing substances and critical insecticides were allocated for use only on vital crops for which no satisfactory substitute insecticides were known. These controls were exercised by the War Production Board with the technical guidance of the Bureau of Entomology and Plant Quarantine.

Ultimately the arsenic situation improved, and consumption figures for lead arsenate reached 74 million pounds in 1943. In that year, however, calcium arsenate consumption dropped about 15 million pounds from 75 million pounds in 1941. The pyrethrum and rotenone situation tightened, the former largely as a result of increasing military requirement for insecticides and the latter because of lost sources of supply and dwindling carry-over. Cryolite (sodium fluoaluminate) was in good supply, and it assumed a broader field of application partly as a substitute for arsenicals and partly to fill the gap left by the shrinking supply of rotenone. Both the synthetic and natural cryolite were found useful in the control of a number of destructive pests. The consumption of cryolite for insecticidal uses increased from 6 million pounds in 1942 to 15 million the following year. Another fluorine compound, sodium fluosilicate, came into extensive use in grasshopper and cricket baits in lieu of sodium arsenite, which before the war was used for these purposes to the extent of 7,250,000 in a single year.

Copper, although demanded for many war needs, was made available in fairly adequate quantities for the manufacture of paris green and copper sulfate. As a matter of fact, paris green production increased from about 2 million pounds in 1941 to 3,888,000 in 1943, and nearly as much was available in 1944. Exports greatly increased, however, reaching nearly 915,000 pounds in 1943.

The shortage of pyrethrum was keenly felt by farmers, home owners, and dealers, as that material had gained a place in practically every household as an all-purpose insect spray and was depended upon almost exclusively for the control of certain crop pests, such as the celery leaf tier and cranberry insects. Our major source of pyrethrum a few years ago was Japan. From that country we imported during the 1930's from 9 million to nearly 18 million pounds annually. In 1940 these

imports dropped to about 2 million pounds with less in 1941, and of course none in 1942. Small quantities also came from the Balkans, especially Yugoslavia, and that supply also dwindled and stopped entirely in 1941. Fortunately British East Africa began producing pyrethrum in 1935. This was of high quality and the increase in production kept pace with the decline in the Japanese supply, until 10 million pounds was produced in 1940. The short pyrethrum crop and transportation interference dropped imports from Kenya from the 10 million pound level attained in 1940 and 1941 to about 6 million pounds in 1943 and 7,685,000 in 1944. Brazil helped materially in meeting this serious shortage by providing us with over 2 million pounds in 1944, although this product was of lower pyrethrin content.

Since the military required practically the entire production of pyrethrum, primarily for use in the now famous aerosol bombs, this material became unavailable for use in household and livestock sprays. As a result there was a large increase in the manufacture and consumption of the thiocyanates.

SOME NEW INSECTICIDE DEVELOPMENTS.—Research in the insecticide field has been pressing forward at an unprecedented pace. Federal and State agencies have been doing their utmost to find and develop new insecticides and repellents. For example, witness the testing of about 8000 materials as insecticides and about 7000 as repellents at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, alone.

The insecticide industry has increased its research and testing work many fold and is continuing to expand. Cooperation between governmental and industrial groups is closer and more effective than at any time in the past. In my opinion such cooperation is essential to the best interests of the public.

A few of the promising new insecticidal substances and combinations of materials that are under test in various parts of the country will be discussed.

SEED TREATMENTS.—The determination by Cotton & Frankenfeld (1945) that magnesium oxide mixed with stored seed at the rate of 1 ounce per bushel gives excellent protection against insects, when the moisture content of the seed is not over 12 per cent, is of distinct practical value. These workers also found that a dust containing 3 per cent of DDT in a carrier such as pyrophyllite gave excellent control. When magnesium oxide was used as the carrier, a half-ounce of this mixture to a bushel of seed provided effective, inexpensive, and long-lasting protection.

FUMIGANTS.—The determination that methyl bromide will destroy body lice and their eggs and its adaptation to military needs are outstanding accomplishments. Latta & Yeomans (1943) found that this fumigant destroyed all stages of lice in tightly rolled clothing and bedding in 30 minutes when used at the rate of 9 pounds per 1000 cubic feet at 60° F. or above. It was also shown to be suitable for use in gas-resistant bags, in portable chambers, and even in holes dug in compact soil (Latta *et al.* 1946).

In laboratory and farm-bin tests involving a long series of nitriles, iodides, bromides, chlorides, and other organic chemicals, several nitriles and ethylene dibromide showed much promise as constituents of heavier-than-air fumigants for farm-stored grains. Carbon tetrachloride has been proved to be a much more effective grain fumigant than was formerly recognized because of its extremely slow action (Back & Cotton 1942). Recent work by Walkden & Schwitzgebel of the Bureau has shown that the addition of 5 to 10 per cent of ethylene dibromide to grain fumigants greatly increases the mortality of insects in the surface layers. From 2 to 4 gallons of a 90:10 mixture of carbon tetrachloride and ethylene dibromide per 1000 bushels gave excellent control of insects in wheat stored in farm bins. Insects in flour-milling machinery have also been controlled by tri-weekly fumigation of the units with the standard ethylene dichloride-carbon tetrachloride mixture or with a 50:50 mixture of acrylonitrile and carbon tetrachloride. These treatments, however, must be supplemented with other measures for general insect control in the mill.

A soil fumigant which has aroused interest in the last few years is D-D mixture. This is essentially a mixture of 1,2-dichloropropane and 1,3-dichloropropylene. This material, which is now being produced on a large scale, is of particular

value as a nematocide. It also shows promise in the treatment of soils against white grubs and wireworms.

INSECTICIDAL MATERIALS OF PLANT ORIGIN.—*Erigeron or Fleabane and Heliopsis.*—The roots of a Mexican composite reported as *Erigeron affinis*, but later found by E. L. Little and S. F. Blake almost certainly to be *Heliopsis longipes*, and several American species of *Erigeron* were tested in the Division of Control Investigations. Petroleum ether extracts of the Mexican material showed considerable toxicity to houseflies, adult yellow-fever mosquitoes, and squash bug nymphs (Acree 1945). Some of the other species of *Erigeron* were somewhat toxic to certain insects, and further tests, especially of the Mexican plant, are warranted.

Tests conducted at the Orlando, Fla., laboratory of the Bureau showed the Mexican plant material to be highly toxic to the active forms, but not the eggs, of body louse, and not toxic to larvae of *Anopheles quadrimaculatus* Say or to chiggers.

Sabadilla.—This old insecticidal material has taken on new life largely as a result of the work of T. C. Allen and associates (1944) and the war need for more and better insect-killing agents. It seems likely that its use will be increased, though it is doubtful whether it will assume a large place in the insecticide field. The irritating effect of sabadilla dusts and sprays on the operators and the fact that little is known about the toxicity of the material other than that it is highly poisonous to higher animals are limitations to its use.

About 500,000 pounds of dust preparations of sabadilla seed were used in the United States during 1945. This material was employed mainly against harlequin cabbage bugs, squash bugs, chinch bugs, *Lygus* and other plant bugs, and against lice on livestock. The major source of supply is Venezuela, where the seed is gathered by hand from wild plants. A few of the results obtained mainly by Bureau workers follow.

Two or more applications of dust containing 5 to 20 per cent of sabadilla at 20 to 30 pounds per acre were found beneficial in controlling *Lygus* spp. on seed alfalfa but considerably less effective than a single application of 20 pounds of 5 to 10 per cent DDT dust. Good control of chinch bugs in small grain and corn was obtained with heavy single applications of dusts containing 5 to 20 per cent of sabadilla, but minimum effective dosages were not determined. White mineral oil containing alkaloidal extracts of sabadilla injected into the silks of corn ears were no more effective than mineral oil alone for control of the earworm. In cage trials 20 per cent sabadilla dust was ineffective as a contact or stomach poison for grasshoppers, and 12 per cent dust was ineffective against sweetclover weevil adults.

Among the State Experiment Station workers H. D. Tate, G. C. Decker, and Roger Smith each found sabadilla to be fairly effective against squash bugs. It was used as a 5 to 20 per cent dust and as spray at 2 pounds per 100 gallons.

Sabadilla was ineffective against the cotton aphid and boll weevil, but very effective against *Lygus* bugs and stink-bugs. In field tests against these insects it appeared to be about equal to DDT dust.

At the Orlando laboratory sabadilla was found to give complete mortality or paralysis to body lice on exposure to treated cloth for 11 days or longer after treatment. It had no appreciable ovicidal effect. It showed a knock-down time of 1 to 3 hours. Although it was rather effective against chiggers exposed on treated cloth, this effect was largely lost upon rinsing. The mortality of *Anopheles quadrimaculatus* larvae was 50 to 95 per cent when 10 p.p.m. of sabadilla was added to the water in which they were developing.

The finding by Dr. Allen and associates that insecticidal activity of sabadilla seed is enhanced by long storage and by exposure to temperatures of about 150° F. for a short time is of recognized practical value.

Ryania.—Materials prepared from the plant *Ryania speciosa* were shown in 1944 to be very effective in protecting corn against the European corn borer. In 1945 the Toledo, Ohio, laboratory of the Bureau obtained excellent control of the corn borer with three or four applications of spray containing 2 to 4 pounds of *Ryania* per 100 gallons of water. These results agree with preliminary tests made in 1944 at this laboratory, and with results reported by Pepper & Carruth (1945).

In preliminary tests of heavy applications of 50 per cent *Ryania* dust, very good control of chinch bugs was obtained in small grains. A similar dust, however, gave no control of the corn earworm when applied to 3- or 4-day-old silks.

Sprays containing 6 pounds of *Ryania* per 100 gallons largely prevented codling moth larvae from penetrating apples, but stings were present. Very good kills were obtained in laboratory tests at 4 pounds per 100 gallons.

Cage tests conducted by the Division of Cotton Insect Investigations showed 5 per cent of *Ryania* in pyrophyllite to be as effective as sulfur, but much less so than 5 per cent DDT, against the tarnished plant bug on cotton.

In tests conducted by the Division of Truck Crop and Garden Insect Investigations, dust mixtures containing from 25 to 50 per cent of *Ryania* were not effective against the pea aphid in Wisconsin, the pea weevil in Idaho, or the corn earworm on beans in Virginia. These mixtures were less effective than other insecticides against the Mexican bean beetle in Ohio, the squash bug in California, the sweetpotato weevil in Louisiana, the striped cucumber beetle in Ohio, the onion thrips in California, and the harlequin bug and cabbage caterpillars in South Carolina. *Ryania*, therefore, does not appear to be a promising insecticide for truck crops.

Ryania was not promising as compared with DDT, in tests conducted at Orlando against body lice, flies, and mosquito larvae although at 10 p.p.m. in water from 50 to 95 per cent of *Anopheles* larvae were killed.

There is need for more information on the toxicity of *Ryania* to higher animals as well as on possible residue hazards.

Nicotine, Nornicotine, and Anabasine.—Nicotine and nicotine sulfate continue to be our most dependable aphicides. The demand for nicotine insecticides during 1945 exceeded the supply, and this condition is likely to continue during 1946. Under present price levels of cotton and other crops, there will probably be an increased use of calcium arsenate and DDT for insect control, and as a result possibly increasing threats from cotton aphids and other aphid species. This should stimulate interest in compounds related to nicotine.

Bowen & Barthel (1943) have shown that commercial nicotine sulfates contain varying percentages of nicotine and nornicotine. Laboratory tests conducted by G. T. Bottger and C. Bowen of this Bureau against several species of aphids, the large milkweed bug, and red spiders indicate that nicotine and nornicotine are of a similar order of toxicity but that anabasine is more toxic to all except the large milkweed bug. Roark (1945a) has reviewed the recently published information on this subject.

Yam bean.—Interest in the yam bean, or jicama, as an insecticide (Hansberry & Lee 1943) seems to have subsided, and relatively little experimental work with that material was carried on during the past year. This is believed to be partly due to the relatively low toxicity of yam bean preparations to many insects and the limited quantity and the variability of the available materials. The demonstration by Norton (1943) of the presence of rotenone in yam beans is of interest.

SYNTHETIC ORGANIC COMPOUNDS.—*Hydroxypentamethylflavan.*—Preliminary tests on a number of species of insects and mites are under way with 2′-hydroxy-2,4,4,4′,7-pentamethylflavan. Since it has shown some action against the European red mite and the red spider, it was considered for use in combination with DDT. In tests on apples conducted by the Division of Fruit Insect Investigations at Vincennes, Ind., a mixture of 4 pounds of a commercial formulation containing 25 per cent of hydroxypentamethylflavan and 1 pound of DDT to 100 gallons of water held the European red mite and the common red spider infestations to a comparatively low level. No tree injury was noted except on foliage of a weak limb on one tree. The efficacy of DDT against the codling moth was found not to be impaired by the addition of the flavan. In tests at St. Lucie, Fla., in which 1 pound of a dust containing 10 per cent of the flavan compound was applied to a citrus tree infested with the citrus red mite and the citrus rust mite, not more than partial control resulted.

A dust containing 10 per cent of the flavan compound was effective against the corn earworm and the Mexican bean beetle on beans in Virginia, but in Ohio it did not give satisfactory control of the bean beetle. This material was ineffective

against the boll weevil and tarnished plant bug in small-scale tests carried out by the Division of Cotton Insect Investigations. In tests made by the Division of Insects Affecting Man and Animals it has shown much promise against chiggers in the soil, but against human lice it has not been outstanding. From 2 to 5 pounds per acre applied as a spray to chigger-infested tracts reduced the original infestation by 81 to 100 per cent. A dust application of 4 to 8 pounds per acre cut the original infestation by 96 to 100 per cent. These reductions were in evidence during observation periods of 1 to 2 months.

This flavan compound is said to be less injurious to foliage and less toxic to the warm-blooded animals than DDT. Relatively little work, however, appears to have been done in these fields.

Benzene Hexachloride.—Benzene hexachloride, more accurately called 1,2,3,4,5,6-hexachlorocyclohexane, was forcefully brought to the fore as an insecticide by the work of British investigators which was rather fully described by Slade (1945). This material has been called 666, but there are several objections to this designation, principally because it might be confused with certain proprietary products that are used as medicines. The gamma isomer, named gammexane by Slade, which constitutes only 10 to 12 per cent of the commercial product as manufactured in England, is the principal insecticidal component. The British have tested this material against about 35 different insects, and it has been given preliminary tests on a considerable number of insect pests in this country. British workers (Slade 1945) have found it to be highly effective against flea beetles and the grain weevil *Sitophilus granarius* (L.).

The following results, obtained mainly during 1945 by workers in the Bureau of Entomology and Plant Quarantine, indicate some of the possible fields of usefulness and limitations of this material:

Benzene hexachloride, on basis of gamma content, has been found by Gersdorff & McGovran (1945) to be 7 to 11 times more toxic to houseflies and slightly less toxic to adult malaria mosquitoes than para-para′ DDT. McGovran & Piquett (1945) in laboratory tests found benzene hexachloride to be highly toxic to nearly full-grown housefly larvae. The following concentrations, in parts per million, allowed 50 per cent of the flies to emerge as adults: gamma-benzene hexachloride 7, DDT 77, thiourea 81, and borax 924.

Against the motile forms of human lice, the Division of Insects Affecting Man and Animals found crude benzene hexachloride to be highly effective, and reasonably persistent when applied as a 5 per cent powder. It was not markedly ovicidal.

Against *Anopheles quadrimaculatus* larvae the gamma isomer gave 50 to 100 per cent kill at 0.01 p.p.m. of the water in which they were developing.

Benzene hexachloride was the most effective of 75 compounds tested against chiggers at the Orlando laboratory by application to infested soil. A dust or spray applied at the rate of about 10 pounds of commercial material (10 to 12 per cent gamma-isomer content) per acre gave almost complete eradication of chiggers from treated areas. The Savannah, Ga., laboratory found that 2 to 5 pounds per acre of 10 to 12 per cent gamma-benzene hexachloride applied as a spray reduced the number of chiggers present at the time of treatment by 89 to 100 per cent.

In tests on an acre plot of potatoes in Maine a dust containing about 5 per cent of the gamma isomer was found effective against each of the four species of aphids present, giving an average of about 97 per cent control.

The Division of Cereal and Forage Insect Investigations reports that a poorly prepared dust containing about 5 to 7 per cent of the gamma isomer gave very good control of grasshoppers when used at 20 pounds per acre. A good quality of talc dust containing 2 per cent of the gamma isomer applied at 20 pounds per acre gave about 50 per cent kill of grasshoppers. Laboratory and field tests against the African migratory locust with bran baits (0.2 part of crude benzene hexachloride to 40 parts of bran and 60 parts of water) gave better control than sodium arsenite-bran baits (Slade 1945). Benzene hexachloride knocks down white-fringed beetles very quickly but kills them very slowly, possibly by starvation due to loss of coordination. In cage tests 100 per cent kill was obtained with a mixed dust applied at the rate of 1 ounce

of gamma isomer per acre, and 50 per cent kill was obtained with 0.25 ounce. No foliage injury to field crops and ornamentals resulted from applications of 4 ounces of the gamma isomer per acre. Oat, rice, and cowpea seeds and seedlings were not injured by a mixed dust applied at the rate of 2.5 pounds per acre of gamma isomer in the top 3 inches of soil, but germination and growth was stopped by dosages of 5 pounds or more per acre. Preliminary tests indicate that surprisingly small quantities applied to the soil will destroy white-fringed beetle larvae. In small preliminary cage experiments benzene hexachloride (probably containing about 3 per cent of the gamma isomer) was highly effective against the sugarcane borer and the rice stinkbug.

Benzene hexachloride was considered by the Division of Cotton Insect Investigations to be the most promising new material tested against cotton insects (Ivy & Ewing 1946, Stevenson & Sheets 1946). In preliminary cage tests better control of the boll weevil and the cotton leafworm was obtained than with calcium arsenate and of the cotton aphid than with nicotine. Control of the cotton flea hopper, *Lygus* bugs, and stinkbugs was equal to or better than the control obtained with DDT, and considerably better than with the arsenical-sulfur mixtures. It was not so effective against the bollworm as DDT or heavy dosages of calcium arsenate.

In the laboratory tests by the Division of Fruit Insect Investigations the British product, containing 10 to 12 per cent of the gamma isomer, was less effective in codling moth control than equivalent quantities of DDT. Concentrations of 1 to 4 pounds of this material per 100 gallons were tested. In later tests sprays containing 1 pound of the gamma isomer per 100 gallons were found to be highly effective against the codling moth and those containing 8 ounces per 160 gallons, while less effective, were much more so than lead arsenate. At Vincennes, Ind., benzene hexachloride containing 35 per cent of the gamma isomer was ground with kaolin and applied against codling moths on August 30 as a 5 per cent dust and as a spray prepared to contain 8 ounces of the gamma isomer per 100 gallons. The Golden Delicious trees used had been sprayed with DDT in earlier covers. In laboratory-field tests the dust was less effective than the spray, which in turn was less effective than a DDT spray. Harvested fruit from the tree sprayed with benzene hexachloride had a musty flavor that rendered the fruit unsalable. The marked and persistent odor of the commercial material so far available is very objectionable.

A few studies made by the Division of Bee Culture in Arizona on the effects of benzene hexachloride on honeybees in cages indicate that this material is toxic to bees by contact with very minute quantities. The knock-down time was rather short, but death not very rapid.

Much chemical, biological, and toxicological work remains to be done on this promising material before its potentialities and limitations can be defined.

DDT.—The development and practical application of DDT continues to hold the spotlight in the insecticide field. The effectiveness of this material is being demonstrated on additional species from time to time, formulations for various purposes are being devised by governmental and industrial workers, and information is rapidly accumulating on dosages, timing of applications, combinations with other insecticides and fungicides, and methods and equipment for application.

The general availability of DDT in various forms has given opportunity for some evaluation of this insecticide by the public. Many who have been led to assume that DDT is magic are finding that it has definite limitations. It is to be hoped that these people take a practical view of the situation and do not draw the conclusion that DDT is no good because it does not do all they expect. It is our duty as entomologists to continue to guide users so as to avoid mistakes and thus further to gain and hold public confidence.

The labeling and marketing problems involved have been many and diverse. The Production and Marketing Administration has been swamped with requests for advice from manufacturers, processors, and users. It has done a great deal to aid the insecticide industry and to enlighten and protect the public.

There are many things still to be learned about DDT. The most important, it seems to me, are what we might call the

secondary effects of DDT applications. These include its effects (1) on bees and other beneficial forms of life, such as fish and birds; (2) on livestock when fed forage, ensilage, or grain that carry DDT; on poultry fed on insects killed by DDT; and (3) on man when vegetables and fruits treated with DDT are eaten regularly. The finding of DDT in the meat and milk of animals that have been fed considerable quantities of DDT is disturbing and clearly shows the need for extensive investigations in this field. Some of these are under way and plans are laid for others, but it is doubtful whether they are yet adequate to meet the urgent demand for accurate information.

There is little indication that DDT, if properly applied, will injure many species of plants. However, some of the cucurbits, especially squash, are susceptible, particularly while young. There is some question about the safety of heavy applications to the soil at one time or over a period of several years. Some accelerated tests by the Bureau of Plant Industry, Soils, and Agricultural Engineering and the Bureau of Entomology and Plant Quarantine have been completed and others are under way. These involve detailed studies of this problem under controlled conditions as well as more practical tests. The type of soil involved appears to be an important factor, and extensive plot tests should be made in many parts of the country.

For a review of the many new findings with reference to DDT, readers are referred to the bibliographies by R. C. Roark (1944, 1945b and c) in which 973 references are given.

1, 1-Dichloro-2, 2-bis(*p*-chlorophenyl)-ethane, a compound related to DDT which has been referred to as DDD, *TDE*, and *Rothane*, has received some attention as an insecticide. Tests at the Orlando laboratory show it to be slower in knock-down and much less persistent in action against lice than DDT. In laboratory tests against *Anopheles* larvae it showed greater toxicity than DDT (Deonier & Jones 1946). In acetone suspension it gave between 50 and 100 per cent kill at 0.0025 p.p.m. Prill, *et al.* (1945) report good knock-down and kills of houseflies in a large Peet-Grady chamber with a concentration of 0.4 gram per 100 ml. of a refined petroleum distillate, and also with 0.15 gram of this analog added to 0.1 gram of DDT in 100 ml. They found DDT and the methoxy and ethoxy analogs to be equally effective against larvae of the southern house mosquito, 50 per cent of the larvae being killed in 20 hours with 0.03 to 0.04 p.p.m. in tap water.

It is toxic to a number of agricultural pests, including the southern armyworm, the southern beet webworm, and the codling moth. In preliminary tests by the Division of Cereal and Forage Insect Investigations *TDE* as an oil emulsion atomized on or injected into corn silk gave good control of the corn earworm and compared favorably with DDT.

In tests in the Pacific Northwest a 5 per cent *TDE* dust was less effective than a 5 per cent DDT dust against the pea weevil and pea aphid. The *TDE* dust was inferior to rotenone against the pea weevil.

The Germans claim that *TDE* can be manufactured more cheaply than DDT. Some of them also claim that it is less toxic to higher animals, although others dispute this.

Methoxy Analog of DDT.—Field tests of methoxy, or anisyl, analog of DDT, which is called di(*p*-methoxyphenyl)trichloroethane, or more properly, 1-trichloro-2,2-bis(*p*-methoxyphenyl)ethane, were conducted by the Division of Truck Crop and Garden Insect Investigations at Norfolk, Va., with a 10 per cent dust on beans. It appeared to be as effective as 0.5 per cent rotenone dust against the Mexican bean beetle, but it was not effective against the corn earworm.

The Division of Cereal and Forage Insect Investigations reports that this analog of DDT gave excellent control of grasshoppers as a 20 per cent dust at 20 pounds per acre and as a 10 per cent dust containing also 0.1 per cent of pyrethrins and 1 per cent of a mixture of substituted piperonyl cyclohexenones at 30 pounds per acre on 0.1 acre plots. In cage experiments against white-fringed beetle adults 2 pounds in 100 gallons of water per acre gave good kill, with quick knock-down but very slow mortality. The beetles remained active but could not coordinate or feed. No foliage injury occurred at 4 pounds or more per acre. Up to 100 pounds per acre, the maximum quantity tested, did not injury plants when mixed

into soil. Preliminary tests indicated that this compound applied to the soil is highly toxic to the larvae of the white-fringed beetle. The material was almost nontoxic to the European corn borer. Complete mortality of the rice weevil and the confused flour beetle resulted from a mixture of this methoxy compound with seed wheat at the rate of 0.1 per cent by weight.

Tests conducted by the Division of Control Investigations indicate that this methoxy compound is less effective than DDT against the southern armyworms, the sugar-beet webworm, and the bean leaf roller.

The Division of Cotton Insect Investigations found that this material was ineffective against the tarnished plant bug, but slightly effective against the boll weevil. It was far less effective on the weevil than calcium arsenate.

Against *Anopheles* mosquito larvae this methoxy compound was much less effective than DDT. Tests made at the Orlando laboratory with fourth-instar larvae gave somewhat erratic results. At 0.005 p.p.m. the material gave a kill of 20 per cent in 48 hours, as compared with 93 per cent for DDT. As a residual spray against houseflies and mosquitoes it was less effective than DDT but showed some promise in that field.

Bromine and Fluorine Analogs of DDT.—A bromine analog of DDT, 1-trichloro-2,2-bis(*p*-bromophenyl)ethane, was found by the Orlando laboratory to be somewhat more toxic than DDT to *Anopheles* larvae. At 0.0025 p.p.m. this material killed 60 per cent of the larvae in 24 hours as compared with 22 per cent for DDT, and 95 per cent in 48 hours as compared with 80 per cent for DDT.

The Division of Control Investigations found in preliminary tests that this bromine analog was less effective than DDT against the squash borer and less toxic than derris to the Mexican bean beetle; also, that its toxicity to the southern armyworm equaled that of lead arsenate. The material was about one-tenth as toxic as DDT to larvae of the housefly but about equal to DDT as a spray against adults of that insect.

The fluorine analog, 1-trichloro-2,2-bis(*p*-fluorophenyl)ethane, called *Gix* by the Germans, was found by Orlando and Beltsville workers to be slower than DDT in knocking down houseflies and less than half as toxic to *Anopheles* larvae. At 0.005 p.p.m. it killed only 5 to 10 per cent of the larvae at 24 and 48 hours, respectively, whereas DDT killed 60 and 95 per cent at that concentration. The Germans claim this analog to be superior to DDT as an agricultural insecticide because of its quicker action.

Sulfones.—Considerable interest is manifest in some of the insecticides developed or used in Germany in recent years. The name "Lauseto neu" has been loosely applied to either phenylchloromethylsulfone or *p*-chlorophenylchloromethylsulfone. German workers claim that the latter is five times as effective as DDT against lice and bedbugs; also that the former is more effective against bedbugs and less against lice, that both are ineffective against caterpillars, beetles, and houseflies, and that trichloroethylene is the best solvent.

In this country chlorophenylchloromethylsulfone has been found by the Orlando laboratory to be less effective than DDT against the body louse; however, it is highly ovicidal. No louse eggs hatched when exposed to solutions containing 0.1 per cent of this compound. Phenylchloromethylsulfone also possesses ovicidal properties and both of these sulfones are long-lasting louse killers.

Hexaethyl Ester of Tetraphosphoric acid.—The German material *Bladan*, of which hexaethyl ester of tetraphosphoric acid is the active ingredient, is claimed to be an excellent substitute for nicotine for aphid control.

Benzyl Benzoate.—The use of benzyl benzoate for the control of scabies in man has received considerable attention in Great Britain (Mellanby 1943). In this country it has been successfully used against lice and scabies in man (Eddy 1944). It may largely supersede sulfur ointment in the control of scabies in man, and it may become useful in the control of scabies on pet animals and perhaps on other domestic animals. This material, when impregnated in clothing, has shown outstanding results against chiggers in its speed of action and its persistence (Snyder & Morton 1946).

Ten materials have been found by the Orlando laboratory to be equal to or better than benzyl benzoate as chigger killers. Of these benzil persisted for three

more washings and phenyl benzoate for two more washings than benzyl benzoate.

Synergists.—The shortage of insecticides, especially pyrethrum, encouraged research on synergists, or activators. Isobutylundecyleneamide was the first compound developed for this purpose on a commercial scale. Following Eagleson's (1942) discovery that sesame oil acts as a synergist for pyrethrum, the Division of Insecticide Investigations determined that sesamin was the active synergistic principle in sesame oil and that related compounds, isosesamin and asarinin, showed similar activity.

The alkaloid piperine, found in black pepper, is also a synergist for pyrethrum. The piperine compounds—sesamin, isosesamin, asarinin, and substituted piperonyl cyclohexenone (available under the name (*D & O-312*)—are characterized by containing a 3,4-methylenedioxyphenyl group.

Further search for activators for pyrethrum and other insecticides appears to be warranted.

THE OUTLOOK.—In the insecticide field it is difficult to predict with any degree of certainty what the future holds. It seems safe to assume, however, that there will be a greatly increased use of insecticides in the United States and in other parts of the world. The publicity given to insect control during the war has made people remarkably insect conscious and desirous of actively fighting pests, especially with insecticides. Outbreaks of insects—those that infest crops and those that affect man—are likely to increase as an aftermath of the war. Increased traffic, especially by air, and the effort to lessen the chance of spreading deleterious insects should lead to the more extensive use of insecticides and fumigants. The part that insects play in the transmission of human and animal diseases is now more generally recognized than it was before the war, and the use of insecticides in combating such dangerous pests as flies, mosquitoes, bedbugs, fleas, and cockroaches will probably increase materially. Competition in the production and marketing of agricultural commodities will soon become keen, and this should stimulate the use of insecticides to guarantee profitable yields of high-quality products and to avoid losses and contamination by insects of food and feed materials in shipment and storage.

In the production of fibre crops such as cotton and wool the need for effective control of insects is apparent if competition is to be successfully met.

L. S. Hitchner (1945), executive secretary of the Agricultural Insecticide and Fungicide Association, has stated in reference to the insecticide and fungicide industry: "It is not a particularly large one compared with some others, but an annual volume of distribution at wholesale amounting to about $50,000,000 protects some $4,600,000,000 worth of farm commodities." Also, "In 1944, according to a survey made by our office, less than $5,000,000,000 worth of crops were treated out of nearly $13,000,000,000 worth of crops produced—less than one-half, and only about one-eighth of all the agricultural acreage of the country was sprayed or dusted. With a $3,000,000,000 annual loss from insects and plant diseases, the need for more and better control is evident."

Material increases in the use of insecticides in other countries is to be expected, and the United States is in a position to take a considerable part in meeting that demand. L. N. Markwood (1945), basing his statement on data gathered by the United States Bureau of Foreign and Domestic Commerce, has indicated that after a period of postwar adjustments the exports of insecticides and fungicides from the United States may amount to $11,000,000 annually, as compared with about $5,000,000 in 1939. Among the more important of these export items are copper sulfate, nicotine sulfate, calcium cyanide, paris green, lead and calcium arsenates, and pyrethrum extract. Other insecticides which will doubtless be exported in increasing quantities are DDT, the thiocyanates, and other synthetic organic compounds.

THE SUPPLY SITUATION.—The supply situation can best be summed up by quoting a statement by S. A. Rohwer (1945) which has just appeared in the November Outlook issue of *The Agricultural Situation.*

"Supplies of insecticides for the 1946 crop year will be adequate or abundant with the exception of two important materials—nicotine and rotenone. In contrast to 1945 and recent preceding years pyrethrum will be available for agricultural use in adequate supply. Supplies

should be abundant for the standard arsenicals—lead arsenate, calcium arsenate, and paris green; the well-known fluorine compounds—cryolite, sodium fluoride, and sodium fluosilicate; the commonly used fumigants—including various forms of cyanide, methyl bromide, carbon bisulphide, and chloropicrin. The various kinds of oils, creosote, dinitro-ortho-cresols, and similar compounds, phenothiazines, diphenylamine, tartar emetic, the mercurials, as well as the numerous kinds of wetters, spreaders, and detergents, should be in adequate supply. The same or even better applies to the standard dust diluents for insecticides. Some of the new insecticides, as well as activators of standard materials which have been developed recently and had limited use during the past season, will be more generally available during 1946. Sulphur, copper, and the various synthetic organic fungicides and their standard diluents should be adequate and, for some materials, abundant.

"Larger amounts of rotenone insecticides will be available than at any time since 1941. The season's supply of rotenone, however, will come from South America and will be appreciably less than the amount used during 1942 which amount included imports from the East Indies. Nicotine insecticides will again be less than needed to meet average uses, and it is expected they will be the one important group of insecticides not adequate for all usual requirements.

"Supplies of the chemical DDT will be freely available for use in producing DDT insecticides and many products will be on the market for 1946. It is not possible at this time to indicate all the uses to be recommended for DDT insecticides or to forecast the quantities that may be available but it seems certain a considerable amount will be available and used. Until the results of the experimental work of the past season are available and state and federal agencies have issued recommendations for the use of DDT insecticides, it is not practical to estimate the effect these new materials will have on the use of various standard insecticides. It may be expected, however, that DDT insecticides will be used for some purposes and in some sections and for some pests heretofore controlled by lead, calcium arsenate, cryolite, rotenone, and pyrethrum. There is, however, no reason to believe that DDT insecticides will replace much more than 25 per cent of the amounts of these materials used for any specific purpose. Various formulations of DDT will be used for any specific purpose. Various formulations of DDT will be used to combat some pests which heretofore have not been adequately controlled. But it would be a grave error for farmers or others to think that DDT insecticides will solve all insect problems, or eliminate the need for other kinds of insecticides."

We are in an era of tremendous developments in the insecticide field and in equipment for the application of insecticides. These fields, which had become more or less stabilized prior to the war, have taken on new life. If the development of DDT has done nothing else than demonstrate to the world that it is possible to discover potent insect killers among chemical groups previously thought to hold little promise for such purposes, that alone is a notable achievement. Results secured with DDT have put new life and hope into research, and it is safe to predict that many new and startling insecticide developments will be witnessed within the next few years.

Synthetic organic insecticides are more or less specific, and no one of them can be expected to be a panacea. The search for materials to strike down the pests that do not yield readily to existing insecticides, and the attempt to discover materials that present a minimum of hazard to plants, beneficial forms of life, and higher animals, including man, must be continued. Furthermore, methods of formulating and applying available materials must be improved to give more effective control at less expenditure of labor and money, and with less chance of producing harmful effects.—5-7-46.

LITERATURE CITED

Acree, F., Jr., M. Jacobson, and H. L. Haller. 1945. An amide possessing insecticidal properties from the roots of *Erigeron affinis* D. C. Jour. Organic Chem. **10**(3): 236–42.

Allen, T. C., R. J. Dickie, and H. H. Harris. 1944. Sabadilla, *Schoenocaulon* spp. with reference to its toxicity to flies. JOUR. ECON. ENT. **37**(3): 400–7.

Back, E. A., and R. T. Cotton. 1942. Industrial fumigation against insects. U. S. Dept. Agr. Cir. 369.

Bowen, C. V., and W. F. Barthel. 1943. Nornicotine in commercial nicotine sulfate solutions. JOUR. ECON. ENT. 36(4): 627.
Cotton, R. T., and J. C. Frankenfeld. 1945. Protecting stored seed from insect attack. U. S. Bur. Ent. and Plant Quar. E-677.
Deonier, C. C., and H. A. Jones. 1946. TDE, 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane, as an anopheline larvicide. Science 103(2662): 13–14.
Eagleson, C. 1942. Sesame in insecticides. Soap and Sanit. Chem. 18(12): 125–7.
Eddy, G. W. 1944. A treatment for head lice, crab lice, and scabies. War Med. 6(5): 319–22.
Gersdorff, W. A., and E. R. McGovran. 1945. Insecticide toxicity studies. Soap and Sanit. Chem. 21(11): 117–21.
Hansberry, R., and C. L. Lee. 1943. The yam bean, *Pachyrrhizus erosus* Urban, as a possible insecticide. JOUR. ECON. ENT. 36(2): 351–2.
Hitchner, L. S. 1945. Outlines of war against insects and fungi. Tex. Citric. and Farming 22(2): 15.
Ivy, E. E., and K. P. Ewing. 1946. Benzene hexachloride to control cotton insects. JOUR. ECON. ENT. 39(1): 38–41.
Latta, R., H. H. Richardson, and J. B. Kindler. 1946. Methyl bromide as a delousing agent. U. S. Dept. Agr. Cir. 745.
Latta, R., and A. H. Yeomans. 1943. Methods and equipment for fumigation of clothing infested with body lice. JOUR. ECON. ENT. 36(3): 402–4.
Markwood, L. N. 1945. Markets abroad for American insecticides. U. S. Dept. Comm., Foreign Commerce Weekly 19(9): 7–11.
McGovran, E. R., and P. G. Piquett. 1945. Toxicity of benzene hexachloride to housefly larvae. JOUR. ECON. ENT. 38(6): 719.
Mellanby, K. 1943. Scabies. Brit. Med. Jour. 4328: 795.
Norton, L. B. 1943. Rotenone in yam bean (*Pachyrrhizus erosus*). Amer. Chem. Soc. Jour. 65: 2259–61.
Pepper, B. B., and L. A. Carruth. 1945. A new plant insecticide for control of the European corn borer. JOUR. ECON. ENT. 38(1): 59–66.
Prill, E. A., A. Hartzell, and J. M. Arthur. 1945. Insecticidal activity of some alkoxy analogs of DDT. Science 101(2627): 464–5.
Roark, R. C. 1944. A list of publications on 2,2-bis(parachlorophenyl)-1,1,1-trichloroethane (called DDT) from 1874 to April 30, 1944, inclusive. U. S. Bur. Ent. and Plant Quar. (Unnumbered publication).
Roark, R. C. 1945a. A review of information on anabasine and nornicotine, 1938–1944. U. S. Bur. Ent. and Plant Quar. E-636.
Roark, R. C. 1945b. A second list of publications on DDT. U. S. Bur. Ent. and Plant uar. E-660.
Roark, R. C. 1945c. A third list of publications on DDT. January through June 1945. U. S. Bur. Ent. and Plant Quar. E-674.
Rohwer, S. A. 1945. Insecticides. U. S. Bur. Agr. Econ., Agr. Situation 29(11): 37–8.
Slade, R. 1945. The gamma isomer of hexachlorocyclohexane (gammexane) an insecticide with outstanding properties. Soc. Chem. Indus. Jour., Chem. and Indus. 40: 314–9.
Snyder, F. M., and F. A. Morton. 1946. Materials as effective as or better than benzyl benzoate for impregnating clothing against chiggers. JOUR. ECON. ENT.
Stevenson, W. A., and L. W. Sheets. 1946. Benzene hexachloride to control bugs on cotton. JOUR. ECON. ENT. 39(1): 81.

Organic Compounds Effective Against Larvae of *Anopheles quadrimaculatus*—Laboratory Tests[1]

CHRISTIAN C. DEONIER, HOWARD A. JONES,[2] and HARRY H. INCHO,[3] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In search for new mosquito larvicides at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, screening tests were made on more than six thousand organic compounds[4] to determine their toxicity to fourth-instar larvae of *Anopheles quadrimaculatus* Say.

Richardson & Shepard (1930) used larvae of *Culex pipiens* L. in their study of nicotine and its relatives. Campbell *et al.* (1934) studied the effects of sulfur compounds on *C. pipiens*, *C. restuans* Theob. (=*C. territans* Walk.), and *C. quinquefasciatus* Say. Fink *et al.* (1938) found *C. pipiens*, *C. nigripalpus* Theob., *C. salinarius* Coq., and *C. quinquefasciatus* to be equally susceptible to organic compounds, and used the last species in a

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.
[2] Now with the Unit of Entomological Research, Dodge & Olcott, Inc., Baltimore, Md.
[3] Sergeant, AUS, assigned from Army Air Forces Committee on Aerial Dispersal of Insecticides at Army Air Forces Center, Orlando, Fla.
[4] Some of these compounds were prepared by the Division of Insecticide Investigations; others were obtained from commercial producers.

Table 1.—Results of tests with various compounds giving mortalities of 50 per cent or more at 0.1 p.p.m. to fourth-instar larvae.

Compound	Concentration	Mortality in 24 hours	Mortality in 48 hours
	P.p.m.	*Per Cent*	
Acetic acid, 1-trichloromethyl-2,2'-methylene bis(4,6-dichlorophenyl) diester	0.1	70	100
	.05	50	95
	.025	50	85
	.01	10	45
Arochlor 1248 (chlorinated diphenyl)	10.	100	—
	1.	85	95
	.1	20	50
Benzene hexachloride (crude)	1.	100	—
	.1	81.6	91.6
	.05	36.2	66.2
	.02	4.0	12.5
Benzoic acid, 2,4-dinitro-6-cyclohexylphenyl ester	1.0	90	100
	.1	50	90
	.05	25	100
	.025	10	65
	.01	5	25
2,4-Bis(trichloromethyl)-6-nitro-1,3-benzodioxan	.1	40	95
	.05	10	25
p-iso-Butoxyphenethyl alcohol	1.	0	100
	.1	0	50
Chaulmoogric acid	.1	100	—
	.05	10	30
Dioctylsulfone (mixture of isomers)	1.	100	—
	.1	50	50
Distyryl phenol	10.	80	100
	1.	5	80
	.1	5	65
	.05	0	0
Ethylxanthoacetic acid, isobornyl ester	.1	100	—
	.05	0	5
Fluoroacetic acid, sodium salt	.1	10	65
	.05	0	40
	.025	5	15
Furylacrylic acid, 2-ethylbutyl ester	1.	100	—
	.1	50	50
Naphthenic acid, butyl ester	.1	10	100
	.05	0	0
"Piperonyl cyclohexenone"	10.	60	100
	1.	10	90
	.1	5	50
Salicylic acid, allyl ester	.1	0	90
Synthetic 3956[1]	.01	28.3	98.3
	.005	3.3	58.3
	.0025	1.6	30.0
Thiocyanic acid, 3+(2-cyclohexylphenoxy)propyl ester	10.	100	—
	1.	85	85
	.1	25	75
alpha-Thiocyanopropionic acid, dipentene monocarbinol ester	10.	55	100
	1.	20	65
	.1	0	60
	.05	0	0
Tolane (diphenylacetylene)	10.	100	—
	1.	35	65
	.1	20	50
1-Trichloromethyl-2,2'-methylene bis (6-bromo-4-chlorophenol)	.1	100	—
	.05	95	100
	.025	80	100
	.01	10	75
1-Trichloromethyl-2,2'-methylene bis (4-chloro-6-nitrophenol)	.1	100	—
	.05	5	60
1-Trichloro-2,2-bis (p-chlorophenyl) ethane (or DDT)[1]	.01	100	—
	.005	96.6	98.3
	.0025	58.3	85.0

[1] Only *Synthetic 3956* and DDT were tested simultaneously.

study of 400 organic compounds. Bushland & King (1943) used *C. quinquefasciatus* in tests similar to those herein reported for the evaluation of synthetic organics. In general the *Anopheles quadrimaculatus* used in these tests were more susceptible to toxic agents than *Culex quinquefasciatus*. Only the compounds that caused 50 per cent mortality in 48 hours at 1 part per million (p.p.m.) or less of water are reported here. Since certain compounds related to DDT are to be included in another report only a few of them are listed in this paper.

EXPERIMENTAL PROCEDURE.—The toxicity of these materials was determined in acetone-water suspensions. Tests were made in 400-ml. beakers containing 250 ml. of distilled water. Approximately 25 ml. of the water from each test beaker were poured into a 50-ml. beaker. For each test 20 fourth-instar larvae, selected at random, were placed in the small beaker. A suspension of the chemical being tested was made by adding the required amount of acetone solution to the water remaining in the 400-ml. beaker (approximately 225 ml.), after which the larvae in the small beaker were transferred to the larger beaker. Readings were made after 24- and 48-hour intervals. Larvae that were able to come to the surface when forced to submerge were classed as alive; those unable to do so were considered dead.

In screening the various compounds, initial tests were made at a dosage of 10 p.p.m. If a compound did not give over 50 per cent mortality in 48 hours it was considered non-toxic and no further tests were made.

RESULTS.—Of the 6000 organic compounds, only 175 passed the criterion of 50 per cent mortality in 48 hours at 1 p.p.m. or less. Only the compounds not related to DDT (with exception of a few) are listed below:

Acetic acid, sucrose octoester
Acetic acid, 1-trichloromethyl-2,2'-methylene bis(4,6-dichlorophenyl) diester
Acetone cyanohydrin
Acrylic acid, 2-methylpentyl ester
Acrylic acid, 4-methyl-2-pentyl ester
Acrylic acid, *n*-octyl ester
Alkyl benzyl ethylene glycol ethers
Allyl 3-bromoxenyl ether
2-Amino-4-chloro-6-methylpyrimidine

o-Aminodiphenyl
2-Amino-4-methylpyrimidine
n-Amylchloro-*m*-cresol
o-*n*-Amyloxybenzaldehyde
Anthranilic acid, menthyl ester
APS-202 (chiefly methylnaphthalenes)
Aroclor 1242 (chlorinated diphenyl)
Aroclor 1248 (chlorinated diphenyl)
Aroclor 1254 (chlorinated diphenyl)
Aroclor 1260 (chlorinated diphenyl)
Benzene hexachloride (crude)
Benzenesulfonic acid, *p*-chlorophenyl ester
Benzhydryl methyl ether
Benzoic acid, *o*-allyl-*p*-cresyl ester
Benzoic acid, 2-chloroallyl ester
Benzoic acid, 2-chlorophenyl ester
Benzoic acid, 3,3-dimethyl-5-methylcyclohexyl ester
Benzoic acid, 3,5-dimethylphenyl ester
Benzoic acid, 2,4-dinitro-6-cyclohexylphenyl ester
Benzoic acid, alpha-methylbenzyl ester
Benzoic acid, 3-methylbenzyl ester (impure
Benzyl *p*-bromophenyl ether
Bis (*p*-bromophenyl) ether
2,4-Bis(trichloromethyl)-6-nitro-1,3-benzodioxan
3-Bromoacenaphthene
9-Bromophenanthrene
o-*n*-Butoxybenzaldehyde
o-sec-Butoxybenzaldehyde
p-Butoxycinnamic acid, 2-ethyl-n-hexyl ester
p-iso-Butoxyphenethyl alcohol
2-Butyl-4-chloro-5-methylphenol
4-tert-Butyl-2-chlorophenol
4-tert-Butylphenyl 2-chlorallyl ether
n-Butyl 3-biphenylyl ether
Carbonic acid, *p*-chlorophenyl *n*-amyl ester
Carbonic acid, diphenyl ester
Carbonic acid, 2-methyl-4-chlorophenyl ethyl ester
Carbonic acid, 4-methyl-2-chlorophenyl ethyl ester
Carbonic acid, *p*-tolyl amyl ester
Chaulmoogric acid
Chaulmoogric acid, ethyl ester
Chaulmoogric acid, methyl ester
2-Chloroanthraquinone
Chlorinated turpentine
Chloroacetic acid, 2-methyl-2-nitropropyl ester
Chlorobenzene and carbon tetrachloride reaction product
p-Chlorodiphenyl
Chloroethyl ether from chlorobenzene and carbon tetrachloride reaction product
x-Chloro-*o*-nitrobiphenyl
Chlorothymol
5-Chloro-2-biphenylyl 2-methallyl ether
Cinnamic acid, propargyl ester
p-Cymene chloral condensate
p,p'-Dichlorobenzhydryl *n*-butyl ether
p,p'-Dichlorobenzhydryl ethyl ether
p,p'-Dichlorobenzophenone oxime N-ethyl ether
x-Dichlorodiphenyl ether
4,5-Dichloro-3-methylquinoline
2,4-Dichloro-1-naphthol
Di-o-chlorophenyl acetonitrile
x-Dichlorophenyl xenyl ether
Diethylene glycol isobornyl butyl ether
x,x-Diethyl-2-hydroxydiphenyl
Difluorodiphenyl disulfide
3,4-Dimethoxybenzaldehyde
alpha, beta-Dimethylsuccinic acid, 2-ethyl-*n*-butyl ester (trans)
2,4-Dinitro-6-cyclohexylphenol
2,4-Dinitro-3-methyl-6-*tert*-butylanisole
Dioctylsulfone (mixture of isomers)
1,3-Diphenoxy-2-methylpropane
Diphenyl disulfide
1,5-Diphenyl-2,4-pentadien-1-one
Distyryl cresyl ether
Distyryl phenol
N-Dodecylaspartic acid, dimethyl ester
Epibromohydrin
Ethylxanthoacetic acid, isobornyl ester
Fluoroacetic acid, sodium salt
Furylacrylic acid, benzyl ester
Furylacrylic acid, 2-ethylbutyl ester
1,1,1,2,3,3,3,-Heptachloro-2-fluoropropane
Hexabromobiphenyl
n-Hexyl alcohol
o-*n*-Hexoxybenzaldehyde
Hydnocarpus anthelmintica, oil of
Hydnocarpus galli, oil of
Hydnocarpus wightiana acids, mixed ethyl esters
Hydrocarbon oil (coal-tar fraction)
Hydrocarbon oil, special (coal-tar fraction)
1-Hydroxy-2-acetonaphthone
Indano oxide
p-Iodophenetole
Lauric acid, glycerol monoester
p-Methoxydiphenyl
Myristic acid, diethylene glycol monoester
Myristic acid, glycerol-alpha, alpha'-dimethyl ether ester

Myristic acid, glycidyl ester
Naphthenic acid
Naphthenic acid, butyl ester
Naphthenic acid, glycol ester
Naphthenic acid, tetrahydrofurfuryl ester
5-Nitro-2-beta, beta, beta-trichloro-alpha-hydroxyethoxy-1-beta, beta, beta-trichloro-alpha-hydroxyethyl benzene, anhydro
N-(9-Octadecenyl) dimethylamine
Organic silicon compound (type 500, 50 cstk vis.)
Palmitic acid, glycol monoester
PD-544-B treated (chiefly methylnaphthalenes)
Phenazine
Phenothiazine
N-Phenyl cyclohexylamine
3-Phenyl diphenyl ether
1-Phenyl-3-ethyl-2-heptanol
2-Phenyl-5-hydroxy-1,3-dioxane and 2-phenyl-4-hydroxymethyl-1,3-dioxolane, mixture of acetates
N-Phenyl-beta-naphthylamine
Phthalic acid, di-iso-amyl ester
Phthalic acid, diphenyl ester
"Piperonyl cyclohexenone"
2-Propoxyphenol
Rotenone
Salicylic acid, allyl ester
Salicylic acid, ethyl ester
Salicylic acid, *n*-hexyl ester
Salicylic acid, phenylethyl ester
Synthetic 3956
Terphenyls, mixed isomeric
Tetrachloro-*o*-nitrobiphenyl
Thiocyanic acid, 3(2-cylcohexylphenoxy) propyl ester
Thiocyanic acid, *p*-iodophenyl ester
Thiocyanic acid, alpha-naphthyl ester
alpha-Thiocyanopropionic acid, dipentene monocarbinol ester
Tolane (diphenylacetylene)
Tribromo-beta-naphthol
Trichlorocumene
1-Trichloromethyl-2,2′-methylene bis (6-bromo-4-chlorophenol)
1-Trichloromethyl-2,2′-methylene bis-(4-chloro-6-nitrophenol)
2,3,6-Trichlorophenol
Vinyl 2-biphenylyl ether

More detailed information on 22 of these compounds, which showed mortalities of 50 per cent or over at 0.1 p.p.m., is given in table 1. Acetic acid, 1-trichloromethyl-2,2′-methylene bis(4,6-dichlorophenyl)diester; benzene hexachloride; and *Synthetic 3956* were superior to the other compounds in their toxicity to anopheline larvae. The gamma isomer of benzene hexachloride was also tested and found to be more highly toxic than the crude product, which contains only 10 to 12 per cent of the gamma isomer.

SUMMARY.—Of the 6000 organic compounds tested to determine their toxicity to fourth-instar larvae of *Anopheles quadrimaculatus* Say only 175 gave mortalities of over 50 per cent in 58 hours at 1 p.p.m. Twenty-two compounds, in addition to DDT and related compounds, showed toxicity at 0.1 p.p.m. Acetic acid, 1-trichloromethyl-2,2,-methylene bis(4,6-dichlorophenyl) diester; benzene hexachloride; and *Synthetic 3956* were superior to the other compounds in their toxicity to anopheline larvae.—5-27-46.

LITERATURE CITED

Bushland, R. C., and W. V. King. 1943. Laboratory tests with organic compounds as larvicides for *Culex quinquefasciatus* Say. U.S.B.E.P.Q. **E-585.**

Campbell, F. L., W. N. Sullivan, L. E. Smith, and H. L. Haller. 1934. Insecticidal tests of synthetic organic compounds—chiefly tests of sulfur compounds against culicine mosquito larvae. JOUR. ECON. ENT. **27**(6): 1176–85.

Fink, D. E., L. E. Smith, D. L. Vivian, and H. V. Claborn. 1938. Toxicity tests with synthetic organic compounds against culicine mosquito larvae. U.S.B.E.P.Q. **E-425.**

Richardson, C. H., and H. H. Shepard. 1930. The effect of hydrogen-ion concentration on the toxicity of nicotine, pyridine, and methylpyrrolidine to mosquito larvae. Jour. Agr. Res. **41**: 337–48.

DDT Applied from the Ground for Control of Mosquitoes[1]

A. H. Madden, Arthur W. Lindquist, and E. F. Knipling,[2] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Extensive tests on the use of DDT as a finely atomized spray against adult mosquitoes in outdoor habitats were made in 1943 and 1944 (Madden *et al.*, 1946). Further experiments were conducted during the summer of 1945 to determine the effect of various factors on the control obtained by such treatments. The work involved the treatment of over 100 acres of jungle terrain.

The test area was located near Mims, Fla., in a rather heavy jungle-like growth consisting of a mixed stand of hardwoods and cabbage palms. The mosquito population was composed mainly of the salt-marsh species *Aëdes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.), but a moderate number of fresh-water breeders (mostly *Psorphora* spp.) were noted occasionally. Although DDT was used in most of these tests, the findings should apply equally well to the similar use of other contact insecticides.

Methods.—Spray applications were made with hand-operated paint sprayers unless otherwise noted. Treatments were applied to 1-acre square plots, by crossing and recrossing the plot with the sprayer nozzle held horizontally so as to take advantage of the direction of any air movement. The swath width was 20 feet in most cases. To cover an acre with the limited amount of solution employed, the sprayer was used intermittently as the operator moved over the area. Considerable experience and judgment were required to obtain complete and even coverage with some of the smaller amounts of material. Solutions containing 5, 10, and 20 per cent of DDT were used in most of these tests. The 5 per cent solution was made with No. 2 fuel oil, whereas higher concentrations were made with a 50:50 mixture of No. 2 fuel oil and *PD-544-C* (lower fraction of *S/V Culicide Oil B*).

Treatments were evaluated by making counts of the mosquitoes landing on the clothing of an observer in 1-minute intervals both before and after treatment. This method is described in detail by Lindquist *et al.* (1945a). Post-treatment counts were made 1 hour after application to give the DDT time to take effect. In a number of instances percentage control calculated on the basis of counts made in untreated areas that were used as checks was approximately the same as that determined by the pre- and post-treatment counts within the treated plots.

Effect of Equipment.—Recent studies with space sprays under household conditions (Lindquist *et al.* 1945b) have emphasized the need for a consideration of the adequacy of the sprayer used. This factor is particularly important when dealing with concentrated insecticides.

To determine the effect of various types of sprayers on the results obtained against adult mosquitoes under outdoor conditions, two series of tests were conducted in which three types of equipment were compared—(1) a *DeVilbiss*-type paint sprayer (2) an 8-inch capillary-tube sprayer designed by H. O. Schroeder and A. W. Lindquist, and (3) a pressure sprayer. These three types cover a wide range with respect to droplet size and number of air-float particles produced. Both the *DeVilbiss* and capillary-tube sprayers operate by atomization, and there is no great difference between the average diameters of the air-float particles (about 10 microns with the former and 18 microns with the latter, for a liquid of the viscosity of No. 2 fuel oil. The most important difference apparently lies in the number of such particles. The capillary tube sprayer atomizes all the material into air-borne particles. Most of the material is atomized by the paint sprayer into similar particles at full pressure, but as there is a constant drop in pressure during operation the number of coarse particles increases and at least one-third of the material settles out almost immediately after leaving the nozzle and is therefore largely ineffective. The pressure sprayer operates on the principle

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] The assistance of Charles Lewis, Charles Wood, and Bernard Knecht in conducting the work discussed in this paper is gratefully acknowledged. Particle size determinations were made by Corp. G. T. McCollough, A.U.S., assigned from Army Air Forces Committee on Aerial Dispersal of Insecticides, located at Army Air Forces Center, Orlando, Fla.

of air pressure on the spray material in the container. Only a limited number of air-float particles are produced, and with the nozzle orifice used (0.055 inch) the average diameter of such particles was around 136 microns.

In the first series (2 tests) the paint sprayer was tested against the capillary-tube sprayer with a 20 per cent DDT solution applied at the rate of 30 ml. per acre, and in the second series (five tests) it was tested against the pressure sprayer with a 5 per cent DDT solution applied at the rates of 250 and 1000 ml. per acre. At the same dosage the treatments applied with the paint sprayer were significantly less effective (78 per cent) than those applied with the capillary-tube sprayer (94 per cent). Conversely, the treatments applied by the pressure sprayer were significantly less effective (76 per cent) than those applied by the paint sprayer (90 per cent) even though four times the amount of material was used with the pressure sprayer. The comparison of these results is considered valid, since the two series were conducted under the same conditions.

Although the most effective particle size for mosquito sprays has never been determined at the concentration of insecticide employed most of the particles produced by the capillary-tube sprayer must have been within the effective range. A significantly higher degree of control was obtained with the capillary-tube sprayer than with the pressure sprayer (representing the opposite extreme in particle size range) even though 33 times the amount of solution and 8 times the amount of DDT were applied with the latter.

Since the paint sprayer has been used almost exclusively in investigational work of this type, and as it appears to be quite practical for this purpose, a number of additional tests were conducted to establish the limits of its efficiency with respect to concentration of the insecticide. The dosage of 6 grams of DDT was kept constant in each case, thus permitting a decrease in the amount of solution required per acre with each increase in concentration of DDT. The results of this series of tests showed that, when the concentration of DDT was increased from 5 to 10 per cent and the amount of solution reduced from 125 to 60 ml., there was no difference in control after 1 hour (86 per cent), but when the concentration of DDT was increased to 20 per cent and the amount of solution reduced to 30 ml. the control was much lower (72 per cent). Therefore, concentrations of DDT greater than 10 per cent would be impractical, as the smaller amounts of solution required at higher concentrations cannot be dispersed adequately with this type of equipment.

The superiority of the capillary-tube sprayer in dispersing effectively small quantities of concentrated DDT solutions is unquestionable. It is, however, somewhat laborious to use in the treatment of extensive areas, but this is true with the paint sprayer also although perhaps to a lesser extent. There is an obvious need for a light power sprayer that can be easily carried by the operator. Such equipment should incorporate the principle of the capillary-tube nozzle, or some other equally effective method of obtaining small particles, and should not weigh over 10 to 15 pounds (including the insecticide). It is estimated that with such equipment one experienced operator could treat between 50 and 100 acres of jungle in a day under favorable conditions. Although it would be advisable in practice to apply a somewhat higher dosage than was used on these plots, only about 2 to 4 liters of solution would be required, at least half of which could be carried at one time in addition to the equipment.

A dosage of 40 ml. of 20 per cent DDT solution involves the application of only 8 grams of DDT per acre. This forms an interesting contrast to 136 grams of DDT per acre, which is about the amount considered necessary for satisfactory control of adult salt-marsh mosquitoes by airplane spraying. It is possible that in certain areas 8 or 10 men equipped with the power equipment mentioned above could cover a substantial portion of the area treated by a small airplane in an equal number of days, since operations on the ground can be carried on more continuously than from the air. This work could be accomplished at a fraction of the cost of equipment and maintenance necessary with airplane spraying and at a great saving in material, although it is evident that competent men would be required. Furthermore, ground application of the limited quantities of DDT necessary for mosquito control would be less likely to

affect beneficial insects and wildlife than the indiscriminate spraying of larger quantities from the air. Light, portable power equipment certainly would be a useful device in citrus groves and in similar situations where mosquitoes frequently prevent workers from operating. Heavier power equipment mounted on a vehicle, such as a jeep, truck, or tractor, might also be useful for applying ground treatments in relatively open areas, as is pointed out by Madden *et al.*, (1946). The factors affecting the use of hand equipment would also affect the use of this equipment under similar conditions.

METEOROLOGICAL FACTORS.—Several series of tests were conducted to determine the relation between the time of day the treatment was applied and the resultant control. The applications were made at dawn and at midday. It was anticipated that a variation in meteorological factors at different hours of the day would result in a difference in the effectiveness of the spray treatments.

In the first series of tests dosages of 125 and 250 ml. of a 5 per cent DDT solution were applied at dawn and at midday. The control (average of two tests) after 1 hour with the 125-ml. dosage was 86 per cent (dawn) and 85 per cent (midday), as compared with 97 per cent (dawn) and 90 per cent (midday) for the 250 ml. dosage. The best results were obtained with 250 ml. applied at dawn, but this apparently is not significantly better than the results obtained at midday with the same amount of material.

In the second series of tests both a 5 per cent and a 20 per cent DDT solution were used. The 5 per cent solution was applied at the rate of 125 ml. per acre, and the 20 per cent solution at 30 ml. per acre, the dosage of DDT (6 grams) being about the same in the two cases. The control (average of four tests) after 1 hour was 71 per cent (dawn) and 72 per cent (midday) with the 20 per cent solution, as compared with 90 per cent (dawn) and 81 per cent (midday) with the 5 per cent solution. As in the previous tests, there was no significant difference between treatments applied at dawn and at midday.

A 20 per cent DDT solution was also applied with the paint sprayer and the capillary-tube sprayer. At a dosage of 30 ml. per acre the control obtained after 1 hour was 66 per cent (dawn) and 71 per cent (midday) with the paint sprayer, and 91 per cent (dawn) and 84 per cent (midday) with the capillary tube sprayer.

One of the meteorological factors which might affect the successful application of spray treatments is the stability of the atmosphere at the surface layer of the ground. When this layer is stable, there is no movement of spray particles except in a lateral direction. When the ground becomes warmed by the heat of the sun, many fine particles are carried upward by rising air currents, where they may be dissipated by the wind.

Determination of the stability of the surface layer of air may be obtained from temperature readings at 0.3 and 2 meters above the ground.[3] The difference between the temperatures at these two points is known as the lapse rate. A positive lapse rate indicates stability or inversion of the atmosphere and a negative lapse rate indicates convection.

Lapse-rate records were obtained at frequent intervals in the course of these investigations. A representative portion of these records, which were made both in the open and in the jungle, is presented in table 1. These records show that, while the surface layer of air became more turbulent

Table 1.—Lapse rates determined by temperature readings taken at 0.3 and 2 meters above the ground.

DATE	TIME[1]	LAPSE RATE (° C.) IN JUNGLE	LAPSE RATE (° C.) IN OPEN
July 13	11:56 a.m.–12:30 p.m.	0	−1.1
17	11:25 a.m.–11:32 a.m.	0	−1.1
18	7:28 a.m.– 7:32 a.m.	+0.5	0
24	11:20 a.m.–11:30 a.m.	+ .2	− .5
31	11:26 a.m.–11:33 a.m.	+ .2	−1.3
Aug. 1	7:47 a.m.– 7:54 a.m.	0	− .3
	3:26 p.m.– 3:30 p.m.	0	−1.4
2	8:16 a.m.– 8:36 a.m.	+ .3	− .2
	1:21 p.m.– 1:30 p.m.	+ .5	− .6
8	11:27 a.m.–11:40 a.m.	+ .2	− .9
	2:22 p.m.– 2:35 p.m.	+ .3	− .4
9	8:25 a.m.– 8:42 a.m.	+ .6	0
	10:53 a.m.–11:00 a.m.	+ .4	0
	1:35 p.m.– 1:40 p.m.	+ .4	− .6
23	11:42 a.m.–11:51 a.m.	+ .3	−1.4
	1:53 p.m.– 2:23 p.m.	+ .2	−1.6
24	1:30 p.m.– 1:42 p.m.	+ .3	− .6

[1] Eastern War Time.

[3] Standard practice of the Chemical Warfare Service, U. S. Army, in the study of war gases.

in the open as the day advanced, it remained stable in the jungle. Negative lapse rates have been obtained in the jungle but only in open spots where sunlight could reach the surface of the ground.

General observations indicate that wind velocities, which might decrease the effectiveness of spray applications in the open or above the tree tops by drifting the particles away too rapidly, never vary greatly or reach any intensity in the jungle because of the protection afforded by the cover. For the same reason a higher humidity is usually maintained, which may favor the effectiveness of the sprays by reducing the speed of recrystallization of the insecticide from the solvent.

The fact that meteorological conditions remain fairly constant in the jungle is undoubtedly the explanation for the lack of difference between treatments applied at dawn and at midday, as shown by the biological tests. These findings are of much practical importance, since they show that ground spray applications may be made in the jungle at any time of day, and therefore a larger area can be treated in a given time than would be possible if the work had to be limited to a certain optimum period.

SWATH WIDTH.—In all work on finely atomized sprays against adult mosquitoes in the jungle a swath width of 20 feet has been used (Madden *et al.* 1946). It was assumed that this was the maximum width that could be covered adequately even with favorable air movement. During the course of the present investigations tests were conducted in which the effectiveness of 20-foot swaths was compared with that of 40-foot swaths. In the first of these tests a 5 per cent DDT solution was applied at dosages of 125 and 250 ml. per acre. At the lower dosage (average of 5 tests) control was 83 per cent with the 40-foot swath and 90 per cent with the 20-foot swath, whereas at the higher dosage (average of 6 tests) conditions were reversed.

Since the results of the first tests indicated that a 40-foot swath was too wide when a small quantity of liquid was used, other tests were made to determine this point more definitely. To study the application of a minimum quantity of spray, a 20 per cent DDT solution was applied with the capillary-tube sprayer at the rate of 30 ml. per acre. For comparative purposes a 5 per cent DDT solution was applied with a paint sprayer at the rate of 125 ml. per acre. A 40-foot swath width was used in both cases, and the 30 ml. dosage was applied with the capillary-tube sprayer because it was known that this amount of material was less effective when applied with a paint sprayer even in a 20-foot swath. The dosage of DDT was the same in both tests. The control obtained after 1 hour with 125 ml. per acre (91 per cent) was as good as, or better than, could be expected had a 20-foot swath been used. Control with 30 ml. per acre was not only significantly less (69 per cent) than that obtained with 125 ml., but also less than that obtained in all other tests where a 20-foot swath width had been used. This shows that the small amount of concentrated spray needed for effective control, when applied with the capillary-tube sprayer, is inadequate for complete coverage of a 40-foot swath.

These studies show that in general a 40-foot swath may be used without loss of effectiveness when dosages of 125 or 250 ml. of solution per acre are applied with a paint sprayer. This is of practical importance, since it permits the treatment of a given area with half the amount of walking required by the customary method of application. When variable air currents prevented the spray from drifting in the proper direction, less effective results were obtained with a 40-foot swath width. Under optimum conditions of air movement, however, even wider swaths might be covered satisfactorily.

MISCELLANEOUS STUDIES.—Studies were also made to determine the relationship of the solvent to the effectiveness of the DDT sprays being used. Comparative tests were made of DDT in the solvent and of the solvent alone applied at the same rate and with the same equipment. The first of these tests involved the application of No. 2 fuel oil with and without 5 per cent of DDT at dosages of 125 and 250 ml. of spray per acre. At the lower dosage (average of 2 tests) fuel oil alone was only about half as effective after 1 hour as the DDT solution, whereas at the higher dosage it was almost two-thirds as effective.

Additional tests were made to compare the effectiveness of 5 per cent of DDT (6.25 grams per acre) in kerosene with kerosene alone. At a dosage of 125 ml. of spray per acre (average of 2 tests) kerosene

was half as effective as the DDT solution.

Under the conditions of these tests the solvent itself may contribute in part to the effectiveness of the DDT sprays. DDT appears to be more effective in No. 2 fuel oil than it is in kerosene. More directly comparable tests are needed, however, to determine this point conclusively.

Considerable interest has been shown recently in the insecticidal properties of benzene hexachloride. This material has shown promise as a residual spray, as a finely atomized spray, and as a fumigant. The active ingredient is the gamma isomer which constitutes about 12 per cent of the crude material available for testing. During the course of this work an opportunity was afforded to test the effectiveness of this material against that of DDT. Five per cent of crude benzene hexachloride plus 15 per cent of cyclohexanone in No. 2 fuel oil was compared with a 5 per cent DDT solution. Both treatments were applied with paint sprayers at the rate of 125 ml. of solution per acre. Some irritation of the eyes, nose, and throat was experienced by the operator in applying the solution, which may have been due in part to the cyclohexanone in the formula. The dosage of DDT was 6.25 grams per acre, but that of the gamma isomer benzene hexachloride was only approximately 0.75 gram per acre. In four tests of each material the average control with benzene hexachloride was 64 per cent and with DDT 84 per cent. At equal dosages it appears that benzene hexachloride might be even more effective than DDT.

SUMMARY.—Investigations were conducted on the use of finely atomized DDT sprays against adult mosquitoes in the jungle for the purpose of studying various factors which might affect the results obtained by this method of control. A capillary-tube sprayer was found to produce the most effective results with 30 ml. per acre of a solution containing 20 per cent of DDT. Concentrations of DDT greater than 10 per cent were found to be impractical when applied by a hand-operated paint sprayer of the type ordinarily used for this purpose. The need for the development of light power-operated spraying equipment that can be carried is indicated. The time of day that treatments are applied has no bearing on their effectiveness, apparently because meteorological factors, such as lapse rate, wind velocity and relative humidity, remain fairly constant throughout the day under jungle conditions. The use of a 40-foot swath was found to reduce the effectiveness of a 20 per cent DDT solution applied by a capillary-tube sprayer at the rate of 30 ml. per acre. In general, however, a 40-foot swath was found to be just as effective as a 20-foot swath when 125 or 250 ml. of solution per acre was applied by a paint sprayer. Part of the effectiveness of DDT sprays may be attributed to the action of either No. 2 fuel oil or kerosene when there materials are used as solvents. Comparative tests with benzene hexachloride and DDT indicate that benzene hexachloride might be more effective than DDT at the same dosage rate.

LITERATURE CITED

Lindquist, A. W., A. H. Madden, C. N. Husman, and B. V. Travis. 1945a. DDT dispersed from airplanes for control of adult mosquitoes. JOUR. ECON. ENT. **38**(5): 541–4.

Lindquist, A. W., H. O. Schroeder, and E. F. Knipling. 1945b. Concentrated insecticides—preliminary studies of the use of concentrated sprays against houseflies and mosquitoes. Soap and Sanit. Chem. **21**(7): 109, 111, 113, 119.

Madden, A. H., A. W. Lindquist, B. V. Travis, and E. F. Knipling. 1946. Outdoor control of adult mosquitoes with DDT or pyrethrum applied with ground equipment. Mosquito News **6**(1): 7–11.

According to a letter received by Dr. E. O. Essig, the French entomologist Msr. J. M. Mimeur, Colonial Engineer of Agronomy and Entomologist in the Scientific Institute of Cherifien, Morocco, died in France in December, 1945. Msr. Mimeur has published on the insects of French Morocco and has described a number of species in the family Aphididae.

Time Required for *Aëdes vexans* and *A. lateralis* Larvae to Obtain a Lethal Dose of Several Larvicides

W. W. YATES, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Nearly all the mosquito larvicides in general use are efficient only when a surface film is maintained long enough for all the larvae to obtain a lethal dose, either by contact or by ingestion of the poison. Surface deposits may be destroyed or broken by wind and wave action and the movement of aquatic organisms, or solar influences may quickly lower or destroy the effectiveness of some poisons, or evaporate thin films of oil on the water surface. Therefore, the time required by larvae to obtain sufficient poison to kill them after a larvicide has been applied is of practical importance. This paper gives the results of laboratory tests with *Aëdes* larvae that were exposed to toxic applications of several larvicides for different periods of time and were then removed to untreated waters.

MATERIALS AND METHODS.—This investigation covered a period of several years, but the tests with DDT were completed only recently. In the earlier work diesel oil, oil emulsion, 4,6-dinitro-*o*-cyclohexylphenol in an oil emulsion, pyrethrum emulsion, paris green dust, and three preparations of phenothiazine were tested. The more recent work included tests with four DDT preparations. The diesel or light fuel oil (32° to 33.5° Baumé) is the type of oil used locally for the field control of mosquitoes. This oil was also used in preparing the other oil formulations, such as the oil emulsions and the DDT-oil solution. The preparation of the oil emulsions was the same as given by Knipling *et al.* (1943). Emulsions made with *Nopco 1216* (a sulfonated sperm oil) and *Amine 230X* were both tested, but the results were so nearly alike that only those obtained with the first emulsifier are given in this paper.

The pyrethrum emulsion was made according to the standard formula developed by the New Jersey Agricultural Experiment Station, as described by the United States Bureau of Entomology and Plant Quarantine (1938). The 5-per cent paris green dust was prepared by mixing a standard commercial brand with a carrier. Three preparations were made with microfine phenothiazine. The solution in acetone was the same as that used by King (1938). The suspension was prepared with turkey-red oil. The emulsion was one of the best of several made and tested.

The DDT larvicides included one dust and three liquids prepared according to directions published by the United States Department of Agriculture (1946). These larvicides were prepared in very dilute mixtures, because of the small amount of DDT required to kill larvae and the use of small containers for laboratory tests.

All the larvicides, except the phenothiazine suspension, were applied in sufficient amounts to give complete kill within 48 hours when the larvae were left in contact with the poison. The dosages of active ingredient (per acre except for phenothiazine) were as follows:

Pyrethrum-oil emulsion	2 gallons
Oil emulsion	2 gallons
Dinitro-o-cyclohexylphenol-oil emulsion	2 gallons
Unemulsified diesel or light fuel oil	10 gallons
Paris green	2 pounds
Phenothiazine	1 p.p.m.
DDT	0.02 pound
Diesel oil (check)	2.5 gallons

Laboratory-reared fourth-instar larvae of *Aëdes vexans* (Mg.) and *A. lateralis* (Mg.) were used in all tests. These larvae were obtained by flooding dirt taken in lots from natural breeding areas along the Columbia River. In all these lots *A. vexans* predominated, and in some lots this species made up 95 to 100 per cent of the total. Larvae of these two species have been found to differ only slightly in their resistance to larvicides (Stage & Yates, 1941). Most of the tests were made in shallow three- or four-quart pans; a few with paris green and phenothiazine were made in shallow trays holding 10 liters.

Twenty-five larvae were placed in the pans containing tap water at 70 to 75° F.

[1] The writer acknowledges the advice and cooperation of C. M. Gjullin during the course of this investigation, and his assistance and criticism in the preparation of the manuscript.

Table 1.—Comparative effect on Aëdes larvae of several larvicidal treatments after different periods of exposure.

Treatment	Gallons Per Acre	No. of Tests	Hours Exposure	Per Cent Dead or Affected When Removed	Per Cent Mortality After Removal		Per Cent Apparent Recovery[1]
					24 Hours	48 Hours	
Pyrethrum emulsion (standard), diluted 1:9	30	4	0.5	98	74	87	10
		4	1	100	53	94	6
		4	2	100	99	100	0
Diesel oil emulsion with *Nopco 1216* 3%, diluted 1:14	30	3	0.5	72	52	71	3
		4	1	80	66	79	2
		4	2	72	86	97	0
		4	3	85	99	99	0
Dinitro-*o*-cyclohexyphenol 2% in oil emulsion given above, diluted 1:14	30	3	0.5	84	81	93	0
		4	1	98	76	93	5
		4	2	88	87	93	0
		3	3	100	100	100	0
Unemulsified diesel or light fuel oil	10	4	0.5	90	45	64	23
		4	1	100	89	96	4
		5	2	98.5	87.3	91.2	7
		3	3	100	100	100	0
	Pounds						
Paris green, 5 per cent dust	40	3	1	40	87	96	0
		5	2	33	96	97.6	0
	Gallons						
Phenothiazine (solution) 1 gm., *Penetrol* 20 ml., and acetone 5 ml.	2.5	2	1	76	36	80	0
		3	2	93.5	66.7	79	16
		3	3	98.7	29	45.3	51
Phenothiazine (suspension) 1 gm., turkey-red oil 1 gm., water 248 ml.	22.5	4	2	74	16	50.4	24
		2	4	70	32	64	7
Phenothiazine (emulsion) 4.5%, methyl isobutyl ketone 29.2%, vinylite resin 1.8%, diesel oil 60%, Duponol O.S. (an alkyl sulfate) 4.5%, diluted 1:9	14.6	3	2	95	34.7	40	55
		3	4	100	9.3	42	58
	Pounds						
DDT (dust) 0.1%, diluted with talc from 10% commercial dust	20	4	2	6	3	7	0
		6	4	67	30	54.7	18
		5	6	76	40	57.5	22
		4	8	100	52	94	3
		2	Larvae not removed		96	100	—
	Gallons						
DDT (suspension) 0.025%, from stock concentrate preparation of DDT 5 gm., talc 5 gm., *Dreft* (sodium lauryl sulfate, tech.) 2 gm.	10	4	1	14	43	85	0
		5	2	91	84	87	5
		5	4	80	68	95.2	0
		2	Larvae not removed		100	100	—
DDT (emulsion) 0.05%, from stock concentrate preparation of DDT 25%, xylene 68%, *Triton X-100* (an aralkyl polyether alcohol) 7%	5	5	1	24	46.4	79.2	0
		5	2	88	76.8	84	5
		4	4	100	88	98	2
		3	Larvae not removed		100	100	—
DDT 0.1% in diesel oil	2.5	5	1	78	76	93.5	0
		6	2	71	76	86	0
		4	4	91	95	98	0
		2	Larvae not removed		100	100	—
Diesel oil (check for DDT in diesel oil)	2.5	2	1	72	44	68	4
		2	2	68	42	68	0
		2	4	87	52	68	16
		4	Larvae not removed		71	86	—

[1] Where the variation between tests was slight, the figures are the approximate differences between the percentage of larvae dead or affected when removed from the pans and the percentage dead after 48 hours.

and the larvicides uniformly applied with a graduated pipette or small dust atomizer. After the required periods of exposure, the larvae were transferred with an eyedropper to a beaker of fresh water, and from the beaker to pans of fresh water. Food in the form of grass infusion and dog food was given to the larvae in lots that appeared strong enough to feed.

RESULTS.—Table 1 gives the results of these tests. The last column gives the percentage of larvae that obtained non-lethal amounts of the larvicides but enough to affect them temporarily.

The larval mortality obtained from two hours' exposure to the pyrethrum emulsion was equal to that from three hours' exposure to oil emulsions or unemulsified oil. The addition of 2 per cent of dinitro-*o*-cyclohexylphenol to an oil emulsion shortened the time required for the larvae to obtain lethal amounts.

When larvae were exposed to paris green, few appeared to be affected after 1 or 2 hours' exposure, but within 24 hours nearly all were dead and none recovered. Apparently larvae obtained a lethal dose quickly, but the action of the poison is slow.

Results with phenothiazine preparations were erratic. The chemical stupefied

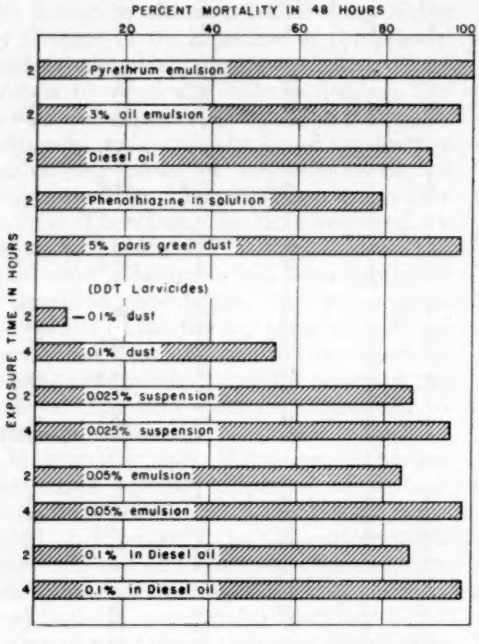


FIG. 1.—A comparison of the toxicity of both dust and liquid preparations containing DDT, and of these materials with other larvicides.

the larvae, but many that appeared dead or moribund recovered when transferred to fresh water. It is apparent that in the small amounts used the poison is very slow in its action, and a long period of contact is necessary to obtain satisfactory results. Phenothiazine gave better results in solution than in suspension or emulsion.

Only a few affected larvae recovered in the lots exposed for one hour or longer to the pyrethrum emulsion, the oil emulsion, the dinitro-*o*-cyclohexylphenol-oil emulsion, or the unemulsified oil. The number of larvae that recovered in phenothiazine-treated lots was high in all tests, and in some tests was more than 50 per cent.

Liquid preparations of DDT killed the larvae much more quickly than did dusts. A two-hour exposure to a 0.1-per cent DDT dust killed only 7 per cent of the larvae, while all three liquid preparations gave a mortality near 85 per cent. A four-hour exposure to the dust increased the mortality to 54.7 per cent, but an exposure of eight hours was necessary to get as good a kill as was obtained with the four-hour exposure to the liquid preparations; the number of larvae that recovered in the dusted pans was also much higher. High mortality in a short exposure was obtained with the DDT in oil, but the oil carrier is itself toxic to larvae. In the check tests made with 2.5 gallons of diesel oil, a majority of the larvae were killed after 1, 2, or 4 hours' exposure.

Figure 1 is a graphic presentation of the results obtained by exposing larvae for two and four hours to both dust and liquid preparations containing DDT. It also compares the effect of DDT with that of several other larvicides on larvae exposed for two hours.

The results of these tests indicate that DDT is slower in its action than the common larvicides but that the time required for larvae to obtain a lethal dose is not excessive. From the standpoint of units of poison the results with DDT are unusual, as a dosage of only 0.02 pound per acre killed all the larvae in 48 hours, as compared with two gallons, or about 14.2 pounds, of oil in an oil emulsion. This means that the particles of DDT are few in number and widely spaced, and larvae will probably not ingest or come in contact with enough poison to kill them in a short time.

Variations between tests using dusts containing DDT were more frequent and of greater magnitude than when a DDT suspension or emulsion was used. The DDT-oil preparation also gave more erratic results than the other liquid larvicides. Table 2 lists several series of tests to show these variations. This table also shows the relationship between mortality and recovery, and that, in some tests where mortality is low, a large number of affected larvae recovered. Toxic action depends in part on the rapidity with which larvae can obtain the poison, and apparently most of the variation between tests is due to the ingestion of sublethal doses of the poison.

SUMMARY. — Laboratory tests with fourth-instar larvae of *Aëdes vexans* (Mg.) and *A. lateralis* (Mg.) show that there is

considerable variation in the length of time required for the larvae to obtain a lethal dose when exposed to different larvicides, including several types of DDT preparations.

Larvae exposed to pyrethrum emulsion obtained a toxic dose in a shorter time than those exposed to oil emulsion or unemulsified oil. Dinitro-*o*-cyclohexylphenol added to an oil emulsion increased the speed of the kill. Larvae treated with paris green obtained lethal amounts quickly, and although the action of the poison was slow, the mortality was high within 24 hours. Phenothiazine is a slow-acting poison and requires long exposure to obtain satisfactory larval control. The initial effect was a stupefaction, from which condition a majority of the larvae recovered when removed from contact with the poison.

DDT is slightly slower in its action than are several of the common larvicides. Larvae exposed to liquid preparations of DDT required four hours to obtain as high mortality as could be obtained in two hours with pyrethrum emulsion and oil larvicides. It was necessary to expose dusts twice as long as liquid preparations to obtain the same results, and when dusts were used a larger number of larvae obtained only enough poison to affect them temporarily. Considering the very small amount of DDT used, and the resultant wide spacing of particles of the poison on the surface of the water, the results obtained with only a few hours' exposure to the poison are remarkable.

Table 2.—Variations in results of tests of DDT as a dust or as liquid preparations.[1]

Treatment	Per Cent Dead or Affected When Removed	Mortality After Removal		Per Cent Apparent Recovery
		24 Hours	48 Hours	
DDT (dust) 0.1%, diluted with talc from 10% commercial dust	72	24	48	24
	48	4	20	28
	84	72	96	0
	60	12	20	40
	80	48	100	0
	60	20	44	16
DDT (suspension) 0.025% from stock concentrate preparation of DDT 5 gm., talc 5 gm., *Dreft* 2 gm.	80	28	80	0
	88	68	100	0
	60	68	96	0
	80	88	100	0
	88	88	100	0
DDT (emulsion) 0.05%, from stock concentrate of DDT 25%, xylene 68%, and *Triton X-100* 7%	100	88	96	4
	100	68	96	4
	100	100	100	0
	100	96	100	0
DDT 0.1% in diesel oil	80	96	100	0
	72	76	92	0
	96	48	72	24
	40	44	56	0
	60	92	96	0
	80	100	100	0

[1] Exposure period 4 hours except for the DDT-oil treatment, when it was 2 hours.

LITERATURE CITED

King, W. V. 1938. Experiments with phenothiazine and mosquito larvae. JOUR. ECON. ENT. **31**(5): 610–1.

Knipling, E. F., C. M. Gjullin, and W. W. Yates. 1943. A new oil-emulsion mosquito larvicide. U. S. Bur. Ent. and Plant Quar. **E-587**.

Stage, H. H., and W. W. Yates. 1941. Comparative resistance of several species of mosquitoes to larvicides. N. J. Mosquito Extermin. Assoc. Proc. **28**: 119–26.

U. S. Bureau of Entomology and Plant Quarantine, Division of Insects Affecting Man and Animals. 1938. Pyrethrum larvicides for mosquito control. U. S. Bur. Ent. and Plant Quar. **E-456**.

U. S. Bureau of Entomology and Plant Quarantine, Orlando, Fla., Laboratory. 1946. DDT and other insecticides and repellents developed for the armed forces. U. S. Dept. Agr. Misc. Pub.

DR. ANDRE GOES TO WISCONSIN

Dr. Floyd Andre, Principal Entomologist with the Office of Experiment Stations, U. S. Department of Agriculture, has been appointed Assistant Director of the Wisconsin Agricultural Experiment Station and Professor of Economic Entomology in the University of Wisconsin. Dr. Andre will terminate his work with the Office of Experiment Stations in August and take up residence at Madison Wisconsin.

Factors Influencing the Rearing and Maintenance of a Laboratory Colony of the Body Louse[1]

G. H. Culpepper, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

The methods and technique used in rearing and maintaining laboratory colonies of the body louse, *Pediculus humanus corporis* Deg., were described in a previous paper (Culpepper 1944). This paper reports a series of tests made in the laboratory of the Bureau of Entomology and Plant Quarantine at Orlando, Fla., from which more precise data[2] on the biology of the body louse established what may be considered the optimum conditions for rearing lice in a laboratory. A daily average of 1900, or a total of approximately 2 million, lice and eggs were used in these experiments during the period May 1942 to May 1945.

Temperature and Humidity.—In 1944 the author stated that conditions favorable for mass rearing of lice required a temperature between 85° and 90° F. and a relative humidity below 75 per cent; also that a humidity of 85 to 90 per cent adversely affected the lice. Up to that time the laboratory colony had been maintained at temperatures of 82.4° to 89.6° and relative humidities of 70 to 80 per cent, closely following the conditions recommended by Moore & Hirschfelder (1919). Wigglesworth (1941) showed that lice in voluntary action prefer a low or medium humidity. Mellanby (1932) found that when the temperature beneath the shirt of a resting person ranged between 73° and 98° the relative humidity was between 23 and 70 per cent.

In efforts to evaluate the importance of certain factors which may influence the rearing and maintenance of a colony of body lice, observations have been made on temperature and relative humidity as they affect longevity and reproductive capacity of lice.

Method and Materials Used in Testing.—The method requires the use of desiccators placed in constant-temperature cabinets. De Khotinsky thermoregulators were used for controlling the temperature. The humidity in the cabinets was maintained as close as possible to that in the desiccators, which was controlled by solutions containing various concentrations of sulfuric acid.

For each test 100 males and 100 females from the main laboratory colony were selected as they were molting to the adult stage. Forty-four tests were made with a total of 8800 adult lice. These lice laid 314,266 eggs during the course of the studies. The lice were kept on pieces of loosely woven woolen cloth, cut round with coping shears to fit the bottom of 50-ml. beakers. The beakers were kept in desiccators at all times except for two feeding periods of about 15 minutes each, one early in the morning and the other late in the afternoon, and one observation period of about 10 minutes each day. Lice and eggs from each test were counted daily, and the lice were changed to new cloth patches after each counting. It is believed that the length of time the lice were left out of the desiccators did not materially affect the results of the tests.

Egg Production.—Information relative to the average length of life and average total egg production at different temperatures and humidities is of special interest in obtaining maximum production of lice. The average egg production per day is derived from the total length of adult life of females and the total egg production. The average daily and average total egg production per female louse at three different temperatures is shown in table 1.

Table 1.—Egg production of female lice at various temperatures and humidities.

Humidity (Per Cent)	Average Number of Eggs per Female					
	Total			Daily		
	90° F.	85° F.	80° F.	90° F.	85° F.	80° F.
90	41.9	67.4	51.7	3.3	3.7	2.0
85	65.0	78.6	—	4.4	4.0	—
75	79.0	97.3	—	4.9	4.4	—
60	78.0	105.7	66.6	4.4	4.5	2.2
30	66.7	68.5	62.1	4.6	3.4	2.0
10	69.8	67.3	57.6	4.5	3.5	1.9

Both temperature and humidity were found to have a highly significant effect

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] F. M. Wadley, of this Bureau, reviewed the data and made all the statistical analyses reported in this paper.

on egg production. The average production per female is definitely higher at 85° F. and a relative humidity of 60 to 75 per cent than at other temperature and humidity settings. However, egg production also holds up well at the lower humidities and is, in general, greater at 30 and 10 per cent than at 90 per cent. Lice may therefore be reared in laboratories and localities where the humidity is as low as 10 per cent. The effect of humidities below 10 per cent was not studied. Buxton (1939) states that body lice are more prevalent during the winter than during the summer. The fact that high temperatures and high humidities adversely affect the life span and reproductive capacity of lice may be further reason for seasonal and area distribution of this insect.

The daily egg production per female was highest in the 60 to 75 per cent relative humidity range and was higher at 90° F. than at 85°. However, table 1 correlated with table 2 shows that increased length of life at 85° and a 60 per cent humidity more than compensated for the slight decrease in daily egg production. In case of necessity for the production of large quantities of lice in the shortest length of time, a colony may be started at 90° and 60 to 75 per cent humidity. After a colony is established, the temperature and humidity should be adjusted nearer to the optima of 85° and 60 per cent.

The daily egg production compared favorably with that described by Buxton (1940), in which his experimental stock produced a mean of 4.03 eggs per day during reproductive life. With a daily production of 4.5 eggs per female and an average adult life of 23.4 days (including 1 pre-oviposition day and the last day of life), the average total production reached 105.3 eggs per louse. The females began laying eggs the second day after they completed the nymphal stage and in many instances continued to lay eggs through the last day of life. Maximum length of life ranged from 28 days at 90° F. and a relative humidity of 90 per cent, to 54 days at 85° and 60 per cent humidity. Therefore, it follows that total maximum egg production ranged from 92.4 to 243 per female. The average daily egg production per female in a laboratory colony fed twice daily was much less than the average number obtained in experiments by Haddow (1941), which show that unmated female lice having continuous access to food lay as many as 13 eggs daily.

Longevity.—Table 2 shows a difference in longevity between temperatures, and a smaller, but significant, difference between humidities. At 85° and 90° F. life was longest at 60 per cent humidity and definitely higher in the 60–75 per cent humidity range. At 80° the life was much longer than at 85° or 90°, and humidity exerted little or no influence at the lower end of the range. Males and females were affected by temperature and humidity to about the same extent.

Table 2.—Effect of temperature and humidity on longevity of lice.

Humidity (Per Cent)	Average Length of Life (in Days)					
	Female			Male		
	90° F.	85° F.	80° F.	90° F.	85° F.	80° F.
90	12.6	18.3	26.0	13.8	15.6	24.4
85	14.6	19.2	—	16.3	19.2	—
75	16.1	21.8	—	19.4	20.7	—
60	17.4	23.4	30.1	18.6	22.5	27.3
30	14.4	20.3	31.1	15.0	21.6	29.6
10	15.4	19.3	30.6	18.1	20.2	29.0

Immature Stages.—The conclusion that a temperature of 85° F. and a relative humidity of 60 per cent are optimum conditions for colony maintenance was based on comparative observations of adult lice. Records were also kept on immature stages reared in this environment. Repeated observations at this temperature and this humidity showed that about 95 per cent of the eggs hatched after an incubation period of 8 to 9 days. Nymphs reached maturity 9 to 11 days after hatching. In some tests nymphal mortality was slight, about 95 per cent of the lice becoming adults. The highest mortality recorded was approximately 15 per cent, most of the loss occurring in the first nymphal instar.

It seems evident that conditions considered most favorable for adult lice are also satisfactory for the eggs and nymphs.

LICE FED ONCE DAILY.—Several tests were made to determine whether lice would survive on only one feeding per day. The methods described for the egg-production and longevity tests were followed in these tests. The desiccators were held at a temperature of 80° F. and a relative humidity of 60 per cent. Two hundred

adult lice were employed. The average adult life of the males was 22.4 days, and of the females 23.4 days. The 100 females laid 4256 eggs, which was a daily average per female of 1.8 or a total of 42.5 eggs per average life. The maximum life of the males was 34 days and of the females 37 days. These tests showed that lice can be maintained in the laboratory on only one feeding per day, but that egg production would not be favorable for rearing large numbers of lice for experimental purposes.

OTHER FACTORS.—Other factors important in the successful rearing and maintenance of a laboratory colony of body lice are sanitation and regularity of feeding. Nymphs should be transferred from the cloth patches containing egg shells to new cloths 24 to 48 hours after they hatch, and should be changed to new cloth again immediately after they reach the adult stage. According to observations made during the last 2 years ,when patches of cloth containing lice are placed on the host for feeding, the lice immediately go beneath the cloth, where they come in contact with the skin and feed in 7 to 12 minutes. In the early work the ordinary electric lamps were placed about 12 inches above the insects to hasten feeding. Further observations indicate that there is no need for electric lamps in the feeding process. At relative humidities of 10 to 75 per cent cloth patches containing lice remain dry, and the accumulations of molted skins and excreta may be removed by rubbing the patches lightly between the hands. The debris falls out, whereas the lice cling to the cloth.

SUMMARY.—Studies conducted at various temperatures and humidities indicate that the optimum conditions for rearing and maintaining a laboratory colony of the body louse, *Pediculus humanus corporis* Deg., are a temperature of 85° F. and a relative humidity of 60 per cent. Adult lice lived an average of 23.4 days under these conditions and the females laid an average of 4.5 eggs each per day, or an average total production of 105.3 per lifetime. Maximum longevity of adults varied from 28 days at a temperature of 90° and a relative humidity of 90 per cent, to 54 days at a temperature of 85° and a humidity of 60 per cent. In most tests mortality began on about the fifth day and increased daily until all lice were dead. The maximum egg production per female varied from 92.4 eggs at a temperature of 90° and a humidity of 90 per cent, to 233 eggs at 85° and 60 per cent humidity.

The optimum conditions of temperature and humidity were also suited to development of immature stages. After an incubation of 8 to 9 days about 95 per cent of the eggs hatched. In 9 to 11 days 85 to 95 per cent of these lice became adults.

A laboratory colony of body lice may be maintained on only one feeding per day at a temperature of 80° F. and a relative humidity of 60 per cent. However, two feedings per day are recommended to obtain a large production of eggs.

Other important factors affecting the successful maintenance of a laboratory colony of body lice are sanitation and regularity of feeding.—4-23-46.

LITERATURE CITED

Buxton, P. A. 1939. The louse. 115 pp. London.

Buxton, P. A. 1940. The biology of the body louse (*Pediculus human corporis:* Anoplura) under experimental conditions. Parasitology **32:** 303–12.

Culpepper, G. H. 1944. The rearing and maintenance of a laboratory colony of the body louse. Amer. Jour. Trop. Med. **24:** 327–9.

Haddow, A. J. 1941. The influence of nutrition on egg-production and longevity in unmated female body-lice (*Pediculus humanus corporis:* Anoplura). Parasitology **33:** 40–6.

Mellanby, K. 1932. The conditions of temperature and humidity of the air between the skin and shirt of man. Jour. Hyg. (London) **32:** 268–74.

Moore, W., and A. D. Hirschfelder. 1919. An Investigation of the louse problem. Minn. Univ., Res. Pub. 8(4).

Wigglesworth, V. B. 1941. The sensory physiology of the human louse, *Pediculus humanus corporis* De Geer, (Anoplura). Parasitology **33:** 67–109.

Life Histories of Some Texas *Phyllophaga*[1]

H. J. Reinhard, *College Station, Texas*

The life history data presented herein were recorded under laboratory conditions during the years 1943 to 1945, inclusive, and are based upon individual rearings by methods previously described by Reinhard (1944). Four species, viz., *Phyllophaga torta*, *P. submucida*, *P. hirtiventris* and *P. rubiginosa*, are included in the study. All are common local forms of potential economic importance.

Phyllophaga torta (Leconte).—The species was originally described by Leconte (1856) from Texas, where it is widely distributed through the central part of the state. Definite records are available from 37 counties extending from the Red River in the north to the lower Rio Grande Valley. Within this region, which perhaps includes the most important pecan-growing areas of the state, the beetles frequently cause severe defoliation of orchards during June and July. Practically all varieties of native and imported elms are likewise subject to extensive damage. Other food plants recorded for the species include plum, hackberry, rose and fig. Aside from one record in which *P. torta* larvae were definitely associated with extensive injury to a young wheat crop in Hardeman County in 1937, little or no information is available concerning other cultivated crops attacked by the grubs. They have proved troublesome on occasion by attacking golf greens and also the grubs have been collected from the soil feeding on the roots of cotton but not in numbers sufficient to produce noticeable injury.

The adult of *Phyllophaga torta* is a glabrous, subshiny, light reddish brown beetle ranging from 19 to 25 mm. in length. Both sexes are robust but the female averages slightly larger in size and is more distinctly widened posteriorly. Perhaps the most nearly exclusive characters in the male are the shape and articulation of the inner hind tibial spur. The latter is inserted at the side near the tip of the tibia; rectangularly bowed inward near the middle and thence decurved terminating in a blunt or subtruncate tip. The genitalia in both sexes are also distinctive and have been illustrated by Sim (1928) and Böving (1942).

Life Cycle.—It may be mentioned at the outset that *Phyllophaga torta* is one of the spring-pupating forms and the beetles do not emerge until late May to July or after the growing season is considerably advanced. After a brief feeding period, during which the beetles mate, oviposition begins and is general in the field by mid June. The duration of the egg stage, as determined in these studies, ranged from 14 to 22 days and averaged 18.5 days. Table 1 shows a summary of the records secured on 1602 eggs laid from June 3 to July 27, 1943. The shortest incubation periods were noted during the latter part of July in temperatures averaging about 74° F.

Table 1.—Duration of egg stage, *Phyllophaga torta*, College Station, 1943.

Date Laid 1943	Number of Eggs Observed	Incubation Period Days			Temperature Average, Daily Mean
		Max.	Min.	Wt. Av.	
June 3–7	3	19	18	18.3	69.5° F.
June 14–16	34	22	21	21.2	70.7
June 16–18	36	21	19	19.9	70.9
June 18–21	111	21	18	19.7	71.0
June 21–23	71	20	18	18.8	71.3
June 23–25	14	20	19	19.2	71.5
June 25–28	158	21	18	19.3	71.7
June 28–30	27	20	18	18.6	71.9
June 30–July ?	144	22	17	19.1	72.4
July 2–6	145	21	16	18.0	72.7
July 6–8	109	20	16	17.7	72.9
July 8–12	189	20	15	16.7	73.1
July 12–15	64	20	17	18.4	73.4
July 15–19	243	22	14	17.2	74.0
July 19–23	137	22	15	17.6	74.3
July 23–27	117	19	14	16.5	74.3
Duration of incubation period				18.5	

With access to suitable and sufficient food the grubs develop rapidly and attain full growth in 90 to 100 days or by the end of October. The mature larvae pass the winter and normally pupate during the following May. However, some rather striking exceptions to this rule were encountered in the individual rearings of the 1943 brood. Among 396 grubs reared to maturity 32 failed to pupate and complete the life cycle in the normal one-year period as indicated by the data in table 2. It may be noted that those grubs which failed to pupate with the bulk of the brood

[1] Contribution No. 956, Division of Entomology, Texas Agricultural Experiment Station.

remained quiescent during the following summer and fall, passed the winter successfully and pupated the next spring. In other words, one additional year was required by this portion of the 1943 brood to complete the life cycle. Since all the larvae were reared simultaneously and under the same environmental conditions, it seems unlikely that the difference in duration of the life cycle is attributable to any imposed condition in the rearing methods. Similar variations in the life cycle of different species have been noted by other investigators, Davis (1916) and Hayes (1920). The reasons for such irregularities in the development of a given species are not known.

The records secured on the duration of the pupal stage are briefly summarized in table 3. The average time required for pupal development was 28 days, with extremes ranging from 18 to 39 days. Weighted averages based upon 236 records showed no significant differences in the rate of development between sexes. The daily mean temperatures averaged 69° F. over the period of observations.

SUMMARY OF LIFE HISTORY.—The beetles emerge in maximum numbers during June and oviposition is well under way during the same month. The average duration of the incubation period is 18 days. With access to ample food, larvae develop rapidly and attain full growth by October. The duration of the larval stage averages about 320 days. The mature larvae pass the winter and pupate from late May through June, requiring about 28 days to complete transformation to the adult. Based upon the average duration of each developmental stage, as determined in these studies, the normal time required for the development of at complete generation is 366 days.

Table 2.—Duration of larval stage, *Phyllophaga torta*, College Station, 1943–44.

Instar	Number of Larvae in Instar for Period Specified						Weighted Average, Days
	22–44 days	45–49 days	60–79 days	211–239 days	240–269 days	270–301 days	
First	374	22					36.6
Second[1]	317	33	14				35.1
Third				62	157	17	247.9
Total larval period							319.6

[1] 32 Long-cycle larvae not included.

Phyllophaga submucida (Leconte).—This species, like the preceding one, was also described from Texas, Leconte (1856), and is even more widely distributed over the state. It has been recorded from 46 counties extending from Nacogdoches to the eastern edge of the Panhandle and southward to the lower Rio Grande Valley. The adults have practically the same food plant preferences as listed for *P. torta* and undoubtedly are fully as destructive to pecan and elm. Additional minor food plants recorded for the species include willow, sycamore, citrus and *Tamarix*.

Table 3.—Duration of pupal stage, *Phyllophaga torta*, College Station, 1944.

No. and Sex of Pupae	Individuals in Pupal Stage for Days Specified									Weighted Average (Days)
Male	*Days*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	
116	No.		4	3	1	2	8	7	6	4	
	Days	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35–39*	
	No.	4	5	7	13	17	12	15	3	5	28.8
Female	*Days*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	
120	No.	1	3	10	11	6	5	5	4	1	
	Days	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35–36*	
		6	5	12	7	15	10	9	8	2	27.4
Average duration of pupal stage											28.1

In relationship *Phyllophaga submucida* seems close to *P. torta*, but the adults differ markedly in general aspect. *P. submucida* is sub-cylindrical in form, rusty red in color and the elytra show a thin but distinct whitish bloom in most views. Aside from its distinctive form and coloration, the species is characterized in the male by having the hind margin of the fifth ventral segment abruptly thickened and acutely granulose. The beetles are rather uniform in size ranging from 19 to 21 mm. in length. The genitalia in both sexes present exclusive characters. The male claspers are symmetrical in structure and approach the general form or type present in *P. torta*. Böving (1942) has illustrated the important differences.

LIFE CYCLE.—The data presented below are based upon rearings made, for the most part, simultaneously and under conditions quite similar to those affecting *Phyllophaga torta*. The essential features of the life cycle are the same. Normally *P. submucida* produces a complete generation in one year. Pupation occurs during the spring and the adults emerge rather late in the growing season, flying in maximum numbers during May and June.

Table 4.—Duration of egg stage, *Phyllophaga submucida*, College Station, 1943.

Date Laid 1943	Number Eggs Observed	Incubation Period, Days			Temperature Average, Daily Mean
		Max.	Min.	Wt. Av.	
May 10–12	30	27	26	26.9	66.5° F.
May 12–17	23	29	28	28.1	67.6
May 19–23	29	28	26	26.4	68.0
May 26–31	62	27	23	23.3	68.8
May 31–June 2	22	24	21	22.2	69.2
June 2–6	69	23	20	21.8	69.6
June 9–11	35	23	19	20.9	70.2
June 11–14	71	22	20	21.1	70.4
June 14–16	17	21	20	20.8	70.7
June 16–18	49	23	20	20.7	70.9
June 18–21	44	21	18	19.5	71.0
June 21–23	31	20	18	19.4	71.3
June 23–25	12	20	19	19.2	71.5
June 25–28	74	21	17	18.9	71.7
June 28–30	49	21	18	18.3	72.0
June 30–July 2	9	19	18	18.4	72.1
July 2–6	55	20	16	17.4	72.6
July 6–8	64	22	16	18.2	73.0
July 8–12	3	16	16	16.0	73.1
July 12–15	45	19	17	18.1	73.4
July 15–19	67	21	17	18.6	73.9
July 19–23	13	18	16	16.9	74.2
July 23–27	18	19	16	17.3	74.3
Duration of incubation period				20.4	

Records secured on the duration of the egg stage are summarized in table 4. It may be pointed out that the observations on the incubation period were begun earlier in the season when temperatures were lower and for this reason the period averaged slightly longer or about 20 days, as compared with 18 days in *P. torta*.

All of the larvae in the rearing series which were kept supplied with ample food attained full growth prior to the dormant season. The latter was passed in this developmental stage. With the advent of the normal pupating period, the bulk of the brood entered the pupal stage during the following May. As in case with *Phyllophaga torta*, a limited number of individuals failed to conform with the normal life history procedure and required one additional year to complete the life cycle. A summary of the records accumulated on larval development is shown in table 5. The first two instars are rather brief, each requiring about 35 days. The third instar, which includes the dormant or overwintering period, is considerably more protracted and required 264 days. In other words, the total larval period averaged 334 days.

Table 5.—Duration of larval stage, *Phyllophaga submucida*, College Station, 1943–44.

Instar	Number of Larvae in Instar for Period Specified						Weighted Average, Days
	21–44 days	45–59 days	60–68 days	209–239 days	240–269 days	270–339 days	
First	332	31	1				35.8
Second[1]	330	25	3				34.2
Third				18	108	80	264.4
Total larval period							334.4

[1] 6 long-cycle larvae not included.

Data recorded on the duration of the pupal stage are summarized in table 6. The time required to complete pupal development averaged about 26 days for both sexes. The maximum time in the stage for any individual was 38 days and the minimum 19 days. In the laboratory the larvae began to pupate on April 29 and the majority of individuals transformed during May. Latest pupation was recorded on July 13. During the period of these observations the effective mean temperatures averaged about 67° F. In summary, the life history of *Phyllophaga submucida* is very similar to the essential features as mentioned under *P. torta*.

Phyllophaga hirtiventris (Horn).—This species occurs less abundantly locally than either of the forms discussed above.

Table 6.—Duration of pupal stage, *Phyllophaga submucida*, College Station, 1944.

No. and Sex of Pupae	Individuals in Pupal Stage for Days Specified									Weighted Average (Days)
Male	*Days* 19	20	21	22	23	24	25	26	27	
100	No. 5	11	5	12	6	4	3	8	4	
	Days 28	29	30	31	32	33	34	35	36–38	
	No. 5	3	1	3	10	6	6	4	4	26.7
Female	*Days* 19	20	21	22	23	24	25	26	27	
102	No. 1	11	11	17	12	2	9	5	3	
	Days 28	29	30	31	32	33	34	35	36–38	
	No. 3	7	3	3	3	3	2	3	4	25.3
Average duration of pupal stage										26.0

It is, however, a fairly common and well known southwestern species. Horn (1887) described it (male only) from Texas without precise locality. The species is now known to be widely distributed over the eastern half of the state, with records of occurrence available from 39 counties extending northwest to Hardeman and southwestward to Medina. Little or no information is available concerning the extent of damage produced by either the adults or the grubs within the large area of its distribution. Field collections indicate that the preferred food plants of the adults are elm, oak, pecan, willow and hackberry about in the order listed.

The adult is a glabrous, reddish brown, feebly shining beetle, which ranges from

16 to 20 mm. in length. Both sexes are moderately robust in build and quite similar in form, which is oblong ovate and slightly depressed. The thickly haired venter in the male is unique and at once distinguishes the species in this sex. But in the female, which lacks the dense vestiture of hairs on the venter, the genital characters offer the best means of identification. The genitalia of one or both sexes have been illustrated by Hayes & McColloch (1920) Sim (1928) and Böving (1942). In this species, as mentioned by Horn (1887), the claws are unusual in having the tooth slightly before the middle and the basal portion of the claw is wider than normal.

LIFE CYCLE.—*Phyllophaga hirtiventris* is a fall-pupating form in which the beetles remain in the pupal cells to pass the winter and emerge with the advent of favorable weather conditions the following spring. The flight period of the adult begins as early as March 3 in the vicinity of College Station but normally the period of maximum adult activity occurs during April. In the laboratory the beetles began to oviposit about the middle of April and

Table 7.—Duration of egg stage, *Phyllophaga hirtiventris*, College Station, 1944.

Date Laid 1944	Number Eggs Observed	Incubation Period, Days			Temperature Average, Daily Mean
		Max.	Min.	Wt. Av.	
April 12–16	67	44	39	41.1	62.5° F.
April 16–20	66	45	39	40.1	63.1
April 20–24	40	41	38	39.6	63.4
April 24–27	47	39	36	37.4	63.7
April 27–29	29	38	35	36.3	64.1
April 29–May 2	52	38	34	36.5	64.4
May 2– 5	47	37	35	36.0	64.7
May 5– 9	14	35	32	33.2	65.1
May 9–12	53	34	31	32.5	65.1
May 12–15	36	34	29	31.1	65.6
May 15–17	14	31	29	29.7	65.8
May 17–19	32	31	28	29.2	66.1
May 22–26	18	29	26	27.5	66.7
May 26–28	4	28	27	27.5	67.2
May 28–31	4	27	25	26.2	67.5
May 31–June 3	9	25	23	23.2	67.8
June 3– 6	23	26	23	24.8	68.4
June 12–14	6	23	20	22.0	70.5
Duration of incubation period				31.9	

continued over a period of about 60 days. Data on the duration of the egg stage are presented in table 7. Based on weighted averages of 561 records the duration of the incubation period totaled about 32 days. This is considerably longer than the corresponding stage in either *P. torta* or *P. submucida*, but it should be noted that the oviposition period in *P. hirtiventris* occurs earlier in the season and lower temperatures obtaining at that time retard the rate of incubation.

Observations on larval development included 311 individuals of which 222 were reared to maturity. These larvae hatched during May and June, 1944, and the majority attained full growth during the following September. The mature larvae

Table 8.—Duration of larval stage, *Phyllophaga hirtiventris*, College Station, 1944–45.

Instar	Number of Larvae in Instar for Period Specified					Weighted Average, Days
	21–44 days	45–54 days	318–329 days	330–364 days	365–403 days	
First	309	2				36.1
Second	288	23				31.2
Third			5	110	107	364.2
Total larval period						431.5

passed the winter and remained quiescent during the succeeding spring and early summer until about mid-July when pupation began. About two-thirds of the individuals pupated during August. A brief summary of the data at hand on the complete larval stage is shown in table 8. The total larval period was found to average about 432 days, which indicates a two-year life cycle. The first two developmental stages are relatively short as in case of one-year cycle species (*Phyllophaga torta* and *P. submucida*) but the third instar averages upwards of 100 days longer since pupation does not occur until late summer or early fall.

Observations on pupal development included 221 individuals, which pupated between July 9 and September 28. The shortest period for any individual in the stage was 18 days, the longest 35 days, and the weighted average, based upon all completed records, was 25 days. Data on the duration of the pupal stage are summarized in table 9. The daily mean temperatures over the period of observation averaged about 73° F.

SUMMARY OF LIFE HISTORY.—The beetles emerge early in the season and fly in maximum numbers during April and oviposition becomes general during the same month. The duration of the egg stage averages about 32 days. The grubs grow rapidly if suitable food is available and become full grown during September. The winter is passed in this developmental stage and the grubs remain quiescent

Table 9.—Duration of pupal stage, *Phyllophaga hirtiventris*, College Station, 1945.

No. and Sex of Pupae		Individuals in Pupal Stage for Days Specified									Weighted Average (Days)
Male	*Days*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	
110	No.	1	4	12	9	8	13	11	9	11	
	Days	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	
	No.	5	6	6	4	3	4	1	2	1	24.8
Female	*Days*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	
111	No.		5	7	9	10	8	7	12	11	
	Days	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	
	No.	8	11	7	7	2	3	1	2	1	25.3
Average duration of pupal stage											25.0

until about mid July when pupation begins. The duration of the larval stage averages about 432 days. Pupae are commonly present during August and about 25 days are required for transformation to the adult stage. The newly transformed beetles remain in the pupal cells, pass the winter and emerge the following spring to complete a two-year life cycle. According to the average duration of each developmental stage as here determined, 489 days are required to produce a complete generation.

Phyllophaga rubiginosa (Leconte).—This is one of the common and well known forms among the species of southwestern *Phyllophaga*. It is generally distributed over the eastern two-thirds of the state extending from the northern to the southern border. In the drier sections of the state, grubs of this species appear to be one of the principal forms concerned in producing injury to pasture grasses. Locally, adults have been collected from a rather wide variety of food plants. Prickly ash, oak and elm seem preferred, but smilax, dogwood and redbud are commonly attacked. Other food plants of apparently lesser importance include rose, plum, hackberry, privet and rattan.

Table 10.—Duration of egg stage, *Phyllophaga rubiginosa*, College Station, 1944.

Date Laid 1944	Number of Eggs Observed	Incubation Period, Days			Temperature Average, Daily Mean
		Max.	Min.	Wt. Av.	
April 25–27	19	40	38	38.7	63.9°F.
April 29–May 1	58	37	35	36.2	64.3
May 9–12	5	33	29	32.0	65.6
May 12–15	34	32	30	31.0	66.1
May 15–17	15	31	29	29.9	66.5
May 17–19	104	31	28	29.3	66.8
May 19–22	74	30	28	28.8	67.1
May 22–26	54	29	27	27.6	67.7
May 26–28	19	26	25	25.3	68.0
May 28–31	27	28	25	26.0	68.6
May 31–June 3	71	25	23	23.9	68.9
June 3– 6	65	27	22	23.6	69.6
June 6– 9	89	25	22	23.1	69.8
June 9–12	70	24	22	22.8	70.0
June 12–14	15	24	22	22.9	70.5
June 14–16	13	24	22	22.9	70.9
June 16–21	86	24	19	21.5	71.2
June 21–24	8	22	20	21.4	71.5
June 24–28	10	20	17	18.1	71.6
June 28–July 2	11	21	18	18.6	72.1
July 7–12	6	19	18	18.3	73.1
Duration of incubation period				25.8	

Horn (1887) described the beetle as oblong oval, scarcely broader behind, ferruginous brown, thorax moderately shining, elytra pruinose, sparsely clothed with semierect hair, longer on thorax and base of elytra; length 15–19 mm. A number of allied species *Phyllophaga aemula*, *P. crenulata*, *P. parvidens*, etc., approximate the habitus of *rubiginosa* but the genital characters in the latter include features that are distinctive, if not exclusive, for both sexes. Hayes & McColloch (1920) have figured and pointed out the principal differences in the female genitalia of *P. rubiginosa* and *P. crenulata*.

Table 11.—Duration of larval stage, *Phyllophaga rubiginosa*, College Station, 1944–45.

Instar	Number of Larvae in Instar for Period Specified					Weighted Average, Days
	27–44 days	45–57 days	327–329 days	330–364 days	365–391 days	
First	341	25				37.5
Second	343	23				37.7
Third			3	199	41	349.0
Total larval period						424.2

LIFE CYCLE.—*Phyllophaga rubiginosa* is also a fall-pupating species and its life history is quite similar to that of *P. hirtiventris*. Locally the overwintering beetles begin to emerge early in March and the flight period extends to the latter half of May. Observations on oviposition in the laboratory were begun on April 25 and continued to July 12, 1944. The duration of the egg stage, as shown by the data in table 10, averaged about 26 days, with a range of 18 to 40 days. It may be noted that as the season advances and temperatures increase, the rate of incubation is accelerated. The shortest periods were recorded in temperatures averaging about 72° F.

From June 3 to July 12, 1944, 366 newly hatched grubs were isolated for detailed rearing records. The majority of these individuals attained full growth by fall and the mature grubs passed the dormant season, remaining inactive until the

following August. At this time pupation occurred generally and continued throughout September. About 68 per cent of the grubs pupated successfully. Table 11 presents a summary of the data accumulated on larval development. The first two instars are relatively brief, each averaging nearly 38 days. The third instar is prolonged since it includes not only the dormant season but also the period over which the larvae remain inactive during the following spring and early summer. The time consumed in this developmental stage is subject to wide variation and was found to average 349 days for 243 individuals under observation. Combined, these figures indicate that 424 days are required to complete larval development, which compares favorably with the corresponding period of 432 days as determined for *Phyllophaga hirtiventris*.

Observations on pupal development extended from August 2 to October 31, 1945. Daily mean temperatures during this period ranged from 62° to 75° F. The available data on duration of the pupal stage are summarized in table 12. Two individuals completed pupal development in 19 days; one required 38 days. The average duration of the period, based upon 243 records, was 28 days.

Table 12.—Duration of pupal stage, *Phyllophaga rubiginosa*, College Station, 1945.

No. and Sex of Pupae	Individuals in Pupal Stage for Days Specified									Weighted Average (Days)
Male	*Days*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	
118	No.	1	4	4	4	5	9	6	10	18	
	Days	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36–38*	
	No.	11	8	5	9	7	8	4	2	3	27.3
Female	*Days*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	
125	No.	1	2	1	5	4	12	6	6	7	
	Days	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36–38*	
	No.	14	11	11	9	8	12	6	3	7	28.8
Average duration of pupal stage											28.0

In summary it may be stated that the present species has a two-year life cycle. About 478 days are required for actual development of a complete generation, distributed among the developmental stages as follows: egg, 26 days; larvae, 424 days; and pupa, 28 days.—4-29-46.

Literature Cited

Böving, Adam G. 1942. A classification of larvae and adults of the genus *Phyllophaga*. Mem. Ent. Soc. Wash., **2.**

Davis, J. J. 1916. A progress report on white grub investigations. Jour. Econ. Ent. **9**: 261–81.

Hayes, William P. 1920. The life histories of some Kansas *Lachnosterna*. Jour. Econ. Ent. **13**: 303–18.

Hayes, William P. and J. W. McColloch. 1920. Some observations on the genitalia of *Lachnosterna*. Ann. Ent. Soc. Amer. **13**: 75–80.

Horn, Geo. H. 1887. Revision of the species of *Lachnosterna* of America North of Mexico. Trans. Amer. Ent. Soc. **14**: 209–96.

Leconte, J. L. 1856. Synopsis of the Melolonthidae of the United States. Proc. Acad. Nat. Sci. Phil. 3(2): 225–88.

Reinhard, H. J. 1944. The life history of *Phyllophaga calceata* and of *P. micans*. Jour. Econ. Ent., **37**: 581–587.

Sim, Robert J. 1928. *Phyllophaga* (Scarabaeidae) of the United States and Canada. N. J. Dept. of Agr., Circ. **145.**

Shepard Heads Insecticide Testing Laboratory

Mr. William M. Davidson retired June 30, 1946, after 35 years' service in the United States Department of Agriculture, and since July 1920, in the Insecticide Division—formerly a division of the Food and Drug Administration, and now a part of the Livestock Branch, Production and Marketing Administration. Since the retirement of the late Walter S. Abbott in 1938, Mr. Davidson has been in charge of the Division's Insecticide Testing Laboratory at Beltsville, Maryland. He is succeeded by Dr. Harold H. Shepard, formerly of the University of Minnesota and for the past year Associate Professor of Insect Toxicology at Cornell University. Dr. Shepard's address is the Insecticide Testing Laboratory, Agricultural Research Center, Beltsville Maryland.

Effect of Phloem Condition and Phloem Moisture on the Entry of *Scolytus multistriatus*[1,2,3]

CHAS. H. MARTIN, *Oregon State College, Corvallis*

From 1935 to 1937 the writer sought for the most effective methods of using elm logs in scouting for *Scolytus multistraitus* Marsham which is a carrier of the Dutch elm disease fungus, *Cerastomella ulmi* (Schwarz) Buisman. A preliminary paper (Martin 1936) reported the results obtained with biweekly cuttings on the relation of the season to beetle infestation of logs; other short notes were included. The effect of light and location of logs on the infestations of *S. multistriatus* and *Hylurgopinus rufipes* (Eich.) was reported later (Martin 1938). Also, a brief summary of a thesis on trap logs was published (Martin 1940).

This paper presents data which correlate the period of attractiveness of a log to *Scolytus multistriatus*, the effect of phloem condition, and of phloem moisture with the number of *S. multistriatus* maternal tunnels found in elm logs.

TECHNIQUE.—Logs were cut at biweekly intervals from May 15 to August 30. Some supplementary cuttings were made during the previous winter.

The logs from each tree were divided between two stations, 40 yards apart, in semi-shade, and were laid side by side on racks consisting of four posts to which were nailed, 3 feet above the ground, two long, horizontal poles. The logs of individual trees within a cutting were randomized on the racks. Twenty logs of each cutting were divided between the two stations.

The technique for making records of the phloem region was as follows: Beran's (1933) method of cutting discs of bark was adopted and an arch punch which cut discs 2 inches in diameter was used. Since the moisture content of the scaly outside bark is dependent on weather, it was removed and the moisture content of the phloem was obtained by drying to constant weight and then calculating the per cent moisture by the formula:

$$\frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100 = \text{per cent moisture.}$$

At the same time a record was made of the appearance of the phloem. If the phloem was the same color as the whitish phloem of live trees the sample was scored as alive. Phloem which was discolored ln the surface, or was streaked with dead phloem, was classified as decadent. Phloem discolored brown from the outside to the inside surface was considered dead.

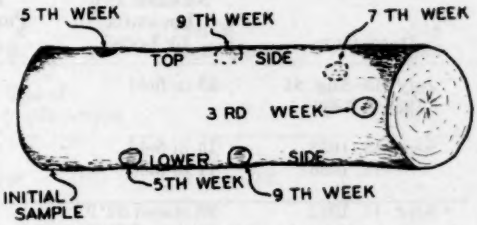


FIG. 1.—Diagram of locations where phloem samples were taken from logs over a period of 9 weeks.

Figure 1 shows the location of the phloem discs taken from each log at each cutting. Each position was selected to give not only a representative sample of the individual log, but also to keep the sample as comparable as possible to the phloem of unsampled logs. The initial sample was taken at the edge of the cut ends because this area showed the first changes in moisture and condition. The samples for the 9th week were taken from the area where the phloem was found to remain unchanged for the longest time. The samples taken from the lower side of the log at the 5th and 9th week were not used in these studies because *Scolytus multistriatus* usually entered the upper two-thirds of the horizontal log.

Logs were examined two or three times a week for beetle entry. Each entry was marked in code with colored wax crayon, so that when the phloem was stripped from the log, the time of entry and the identity of the species could be established.

[1] These data were collected while the author was Research Assistant at Cornell University.

[2] Acknowledgment is due J. K. Holloway for statistical suggestions.

[3] Published as Technical Paper No. 487 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

Such records revealed that many beetles made short, vertical tunnels in the phloem and left without making maternal tunnels. Twenty-four to 80 per cent of the tunnels were continued by the beetles for egg laying. Since the short tunnels seemed to have been for feeding, they have not been included in the counts. Hence, data for this paper deals with phloem which was sought by the beetle for egg laying only.

tion periods had the heaviest infestations of *Scolytus multistriatus*, table 1.

The infestation period included the time between the first and last entries into the log. This period is shown for *Scolytus multistriatus* in table 2 for 2 years. In 1936, records of only the first and the last entries were kept, while weekly records were kept in 1937. The logs were placed at the same stations each year.

Table 1.—The preinfestation period of elm logs prior to entry by *Scolytus multistriatus* and number of entries during the infestation period.

Date Cut	Number and Location of Logs	Length of Preinfestation Period	Infestation Period	
			Date of initial infestation in field	No. beetles entering each cutting for 9 weeks
July 15–Aug. 31 1935 & 1936	30 in field		No infestation	
Sept. 15, 1935	15 in field	8.5 mos.	May 27, 1936	12
15, 1936	11 in field	8.5 mos.	June 1, 1937	1
Sept. 15, 1935	20 stored 32°F.	10+ mos.	Aug. 7, 1936	56
15, 1935	20 stored 60°F.	10 mos.	July 14, 1936	16
Jan. 30, 1936	20 stored 60°F.	5.5 mos.	July 14, 1936	4
30, 1936	48 in field	4 mos.	June 1, 1936	34
Feb. 10, 1937	15 in field	3+ mos.	June 1, 1937	20
April 10, 1937	11 in field	2 mos.	June 1, 1937	11
May 15, 1936	20 in field	2 weeks	June 1, 1936	119
15, 1936	12 stored 60°F.	2 mos.	July 14, 1936	3
May 30, 1936	20 in field	2 days	June 1, 1936	157
30, 1936	10 stored 60°F.	1.5 mos.	July 14, 1936	7

PERIOD OF ATTRACTIVENESS TO *Scolytus multistriatus*.—The attractive period of a log for *Scolytus multistriatus* is divided into two phases: the pre-infestation period, and the infestation period.

The pre-infestation period begins at the time the logs are cut and is completed when the initial infestation occurs. This period may last from a few hours to 2 or 3 days when adult beetles are present, or it may last several months when logs are cut prior to the appearance of the adults (Table 1). Logs kept in the field had a pre-infestation period as long as 8.5 months. This time was extended to 10 months and longer when the logs were kept in cold storage at 32° F., or in basement storage at a mean temperature of 60° F. Logs with the shortest pre-infesta-

Both in 1936 and in 1937, the period of entry was less than 10 weeks and was approximately the same duration for the same cutting each year. The greatest difference was for the June 28 cutting. In 1937, this cutting attracted beetles 4 weeks longer than in 1936. This difference was correlated with unusually hot weather which occurred shortly after the June 28 cutting was made in 1936. The temperatures were not as high in 1937.

When the weekly totals for the 1937 season (Table 2) are considered, the generalization can be made that most of the beetle population was in the log by the end of the fourth week after the initial entry. A decline in the number of entries generally began after the second week.

The peak number of entries for indi-

Table 2.—The fluctuations of *Scolytus multistriatus* entry in logs 1 to 9 weeks old for cuttings made from May 15 to August 17.

Date of Cutting[1]	Number of Weeks after Cutting									Totals
	1	2	3	4	5	6	7	8	9	
May 15, 1936	x	x	x	x	x	x	x	0	0	119
15, 1937	3	26	59	68	6	0	1	0	0	161
May 30, 1936	x	x	x	x	x	x	0	0	0	147
30, 1937	152	121	15	38	8	0	0	0	1	336
June 14, 1936	x	x	x	x	0	0	0	0	0	112
14, 1937	74	221	78	53	7	1	0	0	0	434
June 28, 1936	x	x	0	0	0	0	0	0	0	185
28, 1937	51	101	41	55	33	19	0	0	0	300
July 17, 1936	x	x	x	x	x	x	x	0	0	299
17, 1937	71	50	69	100	66	63	14	12	0	435
Aug. 2, 1936	x	x	x	x	x	x	End of			314
2, 1937	92	190	154	85	46	18	beetle season			585
Aug. 17, 1936	x	x	x	x	End of					122
17, 1937	177	166	97	55	beetle season					495
Totals for 1937 season	620	875	513	454	166	101	15	12	1	

[1] 20 logs were cut on each date.
x = unknown number of entries.

vidual cuttings (Table 2) was associated with the closeness of the cutting date of the log to the peak of beetle abundance in June, or to the major peak of late August, fig. 2. For example, the first beetle peak appeared between June 1 and 15, which was 3 and 4 weeks after the logs were cut on May 15, and just at the time a cutting was made on May 31. The peak number of entries in the former cutting appeared 3 and 4 weeks after cutting, and in the latter 1 and 2 weeks after cutting. There are similar correlations for the rest of the cuttings.

The period of adult beetle activity extended from the last week of May to mid-September (Fig. 2.) Wallace (1940) reports a similar period in southern Connecticut. Because of these limits, only the May and June cuttings ceased to be attractive before the adult season ended. The mid-July cutting, which was 8 weeks old when the adults disappeared in 1937, was near the close of its period of attractiveness when the beetles ceased entering. In 1936, the beetles ceased to enter this cutting 1 week before they ceased to enter the fresher cuttings. The attractive period of the August cuttings extended beyond the beetle season.

PHLOEM CONDITION AND BEETLE ENTRY.—General observations of the appearance of elm trees by Macdougall (1900), Felt (1935), and Readio (1935), indicated that *Scolytus multistriatus* confines its entry for egg-laying to recently killed or decadent trees. Fisher (1928) drew similar conclusions from data on healthy and root-pruned trees.

The writer has taken data which show that the rate of decadence of the phloem is closely correlated with beetle entry for egg laying, while moisture is not related. There were two time elements involved in taking the data. One was related to the age of the logs, while the second was re-

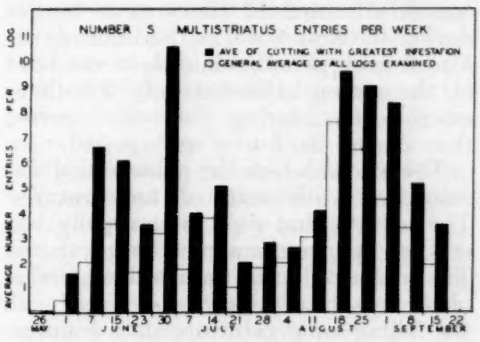


FIG. 2.—The number of *Scolytus multistriatus* entries per week for the season of 1937.

lated to the season that the logs were cut. Also, the condition of the phloem of the log and the moisture content can be considered independently of time. For these reasons, the data are first arranged in table 3 to study the time elements in relation to decadence, moisture, and infestation, and then table 4 presents the data independent of time elements. Phloem condition and phloem moisture will be discussed separately.

creased in degree of importance as the season waned and as the logs became more and more shaded.

When the data are considered independently of time (Table 4), it is obvious that only small numbers of *Scolytus multistriatus* entered the logs when all the phloem in them was dead. In addition to these data, there were nine logs with all dead phloem which were entered when the moisture content of the phloem was

Table 3.—The association of the average number of beetle entries per week with the condition and moisture content of phloem in logs 1 to 9 weeks old.

Data	Age of Logs in Weeks								
	1	2	3	4	5	6	7	8	9
	May and June cuttings								
Ave. entries per log for 80 logs	69.7	117.2	48.2	53.5	13.5	10.0	0.01	0	0.01
Condition of 80 logs	100% alive	—	50% decadent	—	36% dead	—	80% dead	—	100% dead
Ave. per cent moisture	51.9%	—	49.5%	—	45%	—	43.6%	—	40.9%
	July and August cuttings								
Ave. entries per log for 20 to 60 logs	113.3	135.3	106.6	60.0	56.0[1]	40.5[1]	14.0[2]	12.0[2]	0[3]
Phloem condition	100% alive	—	95% decadent	—	3% dead	—	15% dead	—	15% dead
Ave. per cent moisture	49.6%	—	49.4%	—	49.8%	—	49.5%	—	47.3%

[1] July 17 cutting only.
[2] July 17 and August 2 cuttings.
[3] Beetles ceased appearing.

The phloem of logs cut in May and June died more rapidly than those cut in July or August (Table 3). This difference in the rate of dying was associated with a difference in the number of *Scolytus multistriatus* entries made when the logs were 5 to 8 weeks old. Logs cut early in the season attracted 12 times more beetles during the first 4 weeks than during the 5 to 8 week period, while those cut later in the season attracted only 3.3 times more beetles during the initial period than during the 5 to 8 week period.

The rate at which the phloem died was associated with seasonal temperatures. The phloem that died most rapidly was exposed to rising summer temperatures. The prolongation of the decadent period of late season cuttings was associated with the falling temperatures of late summer. Also, the cooler temperature factor in-

less than 40 per cent; they averaged four entries per log. All entry records are for logs in which all of the phloem had been dead less than a month. Beetles did not enter logs when all the phloem had been dead for more than a month. This was observed for several hundred logs over a 3-year period.

There was no significant difference in the number of entries between live and decadent phloem (Table 4). The live category merely indicated that all the phloem area was attractive to the beetles. The decadent category, which included variable amounts of live, dying, and dead phloem, indicated that the maximum attractiveness of the log was declining or had declined.

The beetle's more positive reactions to live or decadent phloem in relation to egg laying may be correlated with the inabil-

ity of the early instars to develop in dead elm tissue. This was demonstrated when small numbers of *Scolytus multistriatus* laid eggs in the logs in which the phloem was killed with hot water. The eggs hatched, but the larvae made long, narrow tunnels without appreciable increase in size and finally perished.

MOISTURE AND BEETLE ENTRY.—Not many studies have been reported on the effect of moisture on the response of bark beetles. Graham (1925) reported a correlation of larval distribution with moisture in fallen trees for two species of bark beetles. Beran (1933) reported similar relations.

Fisher (1928) published observations on the adults of *Scolytus destructor* Oliver (*Scolytus scolytus* F.) and *Scolytus multistriatus* Marsham. He reported that these species were "able to gauge in some manner . . . the moisture (sap) content in a given tree or part of tree, and can distinguish between trees too dry or too moist, or in an intermediate state suitable for egg laying and the development of the larvae of a new generation." He concluded that an average moisture of 32.1 per cent for the xylem region was too wet for the beetles, 28.6 per cent was too low, while 31.8 per cent was suitable.

The writer's data for 1935 (Martin 1936) indicated that there might not be relationship between *Scolytus multistriatus* entry and the moisture in the phloem region of the log. Later, more detailed investigations showed that moisture did not influence the entry of *S. multistriatus* into the logs for the purpose of egg-laying. Four sources of data yielded information on the relation of beetle entry to phloem moisture. Only one of these indicate a correlation while all of the rest indicate no relationship.

The data of early season cuttings indicate a spurious correlation (Table 3). As the average moisture of the May and June cuttings decreased, the average number of beetle entries decreased. This correlation does not appear in late summer cuttings, where the average moisture remained constant while beetle entries declined because of the seasonal decline of the beetle population.

An analysis of the data in table 4 indicated that there was no significant difference between the number of beetles entering phloem within the moisture ranges of 40 to 49 per cent and 50 to 59 per cent.

Table 4.—Influence of phloem condition and phloem moisture on the average number of *Scolytus multistriatus* entries per log per cutting.

Date of Cutting	Condition of Phloem	Per Cent Moisture of Phloem			
		40–49.9		50–59	
		Number of observations[1]	Ave. No. of entries	Number of observations	Ave. No. of entries
May 15	Alive	11	5.2	1	11.0
30		6	6.5	12	8.1
June 14		11	4.0	3	19.0
28		1	11.0	11	10.4
July 17		5	1.8	3	3.0
Aug. 2		4	25.5	13	16.4
Season's average			9.3		11.3
May 15	Decadent	13	3.7	5	9.2
30		12	12.3	1	8.0
June 14		18	11.1	10	9.8
28		10	4.0	14	8.3
July 17		43	7.2	21	5.6
Aug. 2		19	10.6	16	9.0
Season's average			8.1		8.3
May 15	Dead	3	2.0	—	—
30		7	3.1	2	2.5
June 14		4	4.1	—	—
28		6	4.1	1	2.0
Season's average			3.3		2.2

[1] Six hundred observations were made for this table; only observations of entry are recorded. Data for two stations are pooled because the number of beetle entries between stations did not differ significantly.

The moisture content of the phloem of freshly-cut logs and also of approximately two-thirds of the logs with only dead phloem which were over 9 weeks old, ranged from 40.0 to 58.3 per cent. Beetles entered the live logs but did not enter the logs in which the phloem was totally dead, even though the phloem moisture was similar.

The phloem moisture of one-third of the logs which were over 9 weeks old ranged from 20 to 39 per cent, or was over 59 per cent. These extremes of moisture were generally associated with logs in which all of the phloem had been dead for more than a month. Here again, the beetles did not enter the logs because the phloem was dead and old, and not because the moisture was high or low.

Hylurgopinus rufipes.—Kaston (1939) believed that the attractiveness of a log to *Hylurgopinus rufipes* seemed to be intimately related to its water content. This belief was based on the beetles avoiding the top side of a log when it was dried rapidly by the sun. Also, he reported that a log which had lost 20 per cent of its

weight, was no longer attractive to beetles. He found by drying discs of bark and wood that 50 per cent of this weight loss was water loss. He did not correlate the deterioration of the phloem region with beetle entry.

Data taken by the writer for *Hylurgopinus rufipes* show relationships similer to those described for *Scolytus multistriatus*. For this reason these data are not included here. *H. rufipes* was observed to enter dead phloem a little more frequently than *S. multistriatus*, but it generally preferred live and decadent phloem. *H. rufipes* larvae, however, were more successful in dead phloem than those of *S. multistriatus*.

SUMMARY.—When *Scolytus multistriatus* was in the field, the pre-infestation period of elm logs lasted from a few hours to 2 days. When adult beetles were not present, the period for logs left in the field, lasted as long as 8.5 months. The pre-infestation period was extended over 10 months by keeping the logs in cold storage at a temperature of 32° F. or in basement storage at a mean temperature of 60° F.

The infestation period of logs was usually less than 10 weeks. Most of the beetles entered during the first 4 weeks after the initial infestation. The maximum attractive period of only the May and June cuttings ended before the close of the adult beetle season.

Live and decadent phloem attracted several times as many beetles as phloem which had been dead less than 4 weeks; older phloem did not attract beetles.

The data indicated that moisture does not influence beetle entry into logs. When a correlation did appear, it was because moisture is incidentally associated with phloem condition which does influence beetle entry.

Hylurgopinus rufipes reactions to phloem condition and phloem moisture were similar to those of *Scolytus multistriatus*.—4-8-46.

LITERATURE CITED

Beran, O. 1933. Forstentomologische Untersuchungen aus Gebiete von Lunz. III. Untersuchungen über den Verlauf der absoluten Feuchtigkeit in der Kambialzone liegender Fangbäum. Z. angew. Ent. **20**(3): 442–8.

Felt, E. P. 1935. Bark beetles and the Dutch elm disease. JOUR. ECON. ENT. **28**(1): 231–6.

Fisher, R. C. 1928. The relation of elm bark-beetles to their host trees. Forestry **2**(1): 53–61.

Graham, S. A. 1925. The felled tree trunk as an ecological unit. Ecology **6**(4): 397–411.

Kaston, B. J. 1939. The native elm bark beetle *Hylurgopinus rufipes* in Connecticut. Conn. Agr. Expt. Sta. Bul. **420.**

Macdougall, R. S. 1900. Biology and forest importance of *S. multistriatus* Marsh. Proc. Royal Soc. Edin. **23.**

Martin, Chas. H. 1936. Preliminary report of trap-log studies on elm bark-beetles. JOUR. ECON. ENT. **29**(2): 297–306.

Martin, Chas. H. 1938. Effect of sunlight and location of logs on beetle infestation of elm logs. Bul. Brooklyn Ent. Soc. **33**: 195–203.

Martin, Chas. H. 1940. Ecological studies of two elm bark beetles, *Hylurgopinus rufipes* (Eich.) and *Scolytus multistriatus* Marsham. Cornell Univ. Abstracts of Theses **1939.** 290–3.

Readio, P. A. 1935. The entomological phases of the Dutch elm disease. JOUR. ECON. ENT. **28**(2): 341–53.

Wallace, Phillip. 1940. Notes on the smaller European elm bark beetle *Scolytus multistriatus* Marsham. Conn. State Entomologist Report 1939. Conn. Agr. Expt. Sta. Bul **434**: 293–311.

MISSISSIPPI INSTRUCTS AIRPLANE DUSTERS

A meeting for the instruction of airplane dusters was held at Indianola, Mississippi, July 19, with special attention to the application of nicotine on cotton. This was the first meeting of commercial dusting operators in Mississippi. Twenty dusting firms, operating about 600 planes were represented at the meeting by about 75 pilots and other employees. The total attendance of 177 included dealers and salesmen of insecticides and dusting machinery, county agents, entomologists, vocational teachers, planters and others representing agricultural interests.

Instruction in cotton insect control was given by R. C. Gaines and E. W. Dunnam of the Bureau of Entomology and Plant Quarantine, B. J. Young, General Manager of the Delta and Pine Land Company, and Clay Lyle of Mississippi State College. J. B. Ours, Manager of the Dixie Dusting Company, gave valuable suggestions to planters about local landing strips and other important topics.

High-Frequency Electric Fields as Lethal Agents for Insects[1]

HAROLD H. WEBBER, ROBERT P. WAGNER, and ANGUS G. PEARSON[2]

The application of high-frequency electric fields to problems in biology has occupied the attention of a great many workers in medicine, microbiology, plant physiology, and pathology and recently has been demonstrated as a useful tool of the entomologists interested in developing controls of insect pests. By subjecting insects to the influence of Hertzian waves of short or ultrashort wave lengths, it has been shown that a lethal effect is obtained with relatively short periods of exposure (Hadjinicolaou 1931). The effective wave lengths lie in the portion of the electromagnetic spectrum including radio waves, and they extend to the extreme infrared. Probably the first application of this form of energy to biological problems was made by d'Arsonval (1893), who observed marked rises in temperature of laboratory animals when they were exposed to high-frequency fields. D'Arsonval (1896) also demonstrated fundamental changes in bacterial cultures and toxins when exposed to radio waves. Since this initial work, many investigations of the biological influences of high-frequency fields have been made. Outstanding among these is the work of Schereschewsky (1926, 1933), who observed some degree of specificity between frequency and tissue temperature of mice subjected to electric fields between the condenser plates of a high-frequency oscillator. Schliephake (1928, 1929, 1930), working with bacteria, concluded that high-frequency fields induced lethal changes in biological material through the production of lethal temperatures *in situ*, apparently as a result of dielectric hysteresis.

Studies with insects, initiated by Headlee & Burdette (1929), have demonstrated that the high-frequency electric field can be employed as a lethal agent for controlling some insect pests. Studies of the effectiveness of different frequencies for killing insects during the various stages of development and investigations of the effects on different families have been reported (Headlee 1931, 1932, 1933, 1934, 1936). Headlee's conclusions drawn from this work attributed the lethal effect solely to the induction of temperatures reaching the thermal death point of the organism. It was also concluded that the susceptibility of the organism to the influence of the field is a function of the degree of differentiation (stage of development) of the nervous system, since variation between families and variation between developmental stages from the egg to the adult appeared to support this view.

McKinley & Charles (1930), on the other hand, studying the effect of high-frequency fields on parasitic wasps, concluded that there exists an effect other than heat which accounts for the lethality of the field. The extensive literature in this field has been reviewed by Duggar (1936) and Ark & Parry (1940).

The work reported in this paper was undertaken with the aim of testing the use of high-frequency electric fields for the sterilization of [insects in] packaged materials, particularly stored foods and feeds. The term "sterilization" as it is used here is to be understood to mean primarily the killing of insects in the various media, although it is recognized that secondary effects, such as modifications of rates of reproduction or development or both, may occur.

Recent advances in the field of electronics have made available instruments capable of developing electric fields of high intensity. Such a commercial generator was selected for this work, although it was recognized that the range of frequencies available was very limited. It had been demonstrated, however, by Headlee (1929) that these frequencies were capable of inducing lethal changes in insects.

The source of the high-frequency field employed in this research was a *Megatherm* dielectric heating unit manufactured by Federal Telephone and Radio Corporation. The heating oven of this instrument is essentially an electric con-

[1] This work was conducted under the sponsorship of the Office of Production Research and Development, War Production Board.

[2] A contribution of the Research Division of the National Cotton Council of America, The University of Texas, Austin Texas.

denser forming a part of the capacity of the tank circuit of a tuned plate high-frequency class C vacuum tube oscillator. The operating frequency is somewhat dependent upon the load applied between the condenser plates, but throughout this work the frequency approximated 11 megacycles per second.

The field is applied with the specimen between the plates of the condenser mentioned above, the specimen resting on the grounded lower plate. The plates of this condenser, having the dimensions of 25.4 cm. in width, 35.5 cm. in length, are parallel with a separation variable from 0 to 9.85 cm. The feedback required for operation of the oscillator varied according to the load placed in the condenser. It was observed that the voltage produced across the condenser plates varied somewhat with the amount of feedback employed as well as with the separation of the plates and the characteristics of the load. In addition, the voltage across the condenser plates could be varied by means of three taps in the tank coil, which acted as an auto-transformer, as well as by changing the plate voltage of the tube. Provisions were made for the use of either of two plate voltages.

The voltage applied across the condenser plates was measured by means of a capacity potentiometer. A small insulated plate was inserted through a hole in the oven shield in the vicinity of the high voltage plate. Hence the voltage between the small plate and the ground gave a measure of the voltage existing between the plates of the large condenser. The voltage between the small plate and ground was measured by means of a General Radio Company vacuum tube voltmeter. Since the capacity between the small plate and the high voltage plate was so extremely small as not to be measurable by ordinary means, the voltmeter was calibrated by inserting a large auxiliary condenser between the ground and the ordinarily grounded condenser plate of the *Megatherm*. This, together with the capacity of the specimen condenser, formed an auxiliary potentiometer whose capacities could be measured by means of an ordinary A-C bridge with conventional short circuit readings. By alternate measurements of voltage on the two potentiometers, the original potentiometer was calibrated for various plate separations. This voltmeter has the advantages of being independent of frequency and of requiring no lead wires in positions which would endanger the operator.

In order to measure the frequency of oscillation a vacuum tube frequency meter was constructed and calibrated against a General Radio Company wavemeter. With this arrangement the *Megatherm* frequency could be measured anywhere in the laboratory, although the *Megatherm* itself is quite well shielded.

Insertion of a specimen into the test condenser, in general, transforms the tank capacity effectively into a leaky condenser, that is, into a capacity with shunted resistance. The capacity will be increased, since the specimen has an effective dielectric constant greater than air. As a consequence, the frequency and the amplitude of the oscillations are changed. The frequency change, however, is minimized by the fact that the tank condenser forms only a fraction of the total oscillator capacity. The frequency depends primarily on the oscillator capacity. These considerations show clearly why it is necessary to measure the voltage applied to the condenser in order to obtain results which are readily interpretable.

While the measurement of the voltage applied across the condenser plates is relatively simple, it is not always easy to determine the intensity of the electric field applied to the specimen. Specimen here is taken to mean the package of flour, etc. This measurement is of fundamental importance, especially if it is desired to distinguish between temperature effects and effects other than temperature in the killing of insects. It is highly desirable to have a uniform field intensity throughout the specimen. The field intensity within a heterogeneous medium, or applied to an insect surrounded by a homogeneous medium, cannot be readily determined. From the practical point of view, we are interested in knowing what voltage across the plates will be sufficient to kill insects in food packages in a reasonable time, and we are not concerned with the field actually applied to the insects. In the more fundamental biological aspects of the work however, we would like to know the actual field applied to the insects as an aid in determining the cause of death. The sim-

plest requirements for obtaining such a field may be listed as follows:

1. The material must be homogeneous and isotropic.
2. The sides of the specimen must be perpendicular to the plates of the condenser.
3. The sides of the specimen must be far enough from the edges of the plates to avoid edge effects.
4. The specimen must extend all the way from the lower plate to the upper.
5. The frequency must not be high enough for the formation of standing waves on the plates or in the specimen.

If these conditions are satisfied, the field intensity in the specimen is easily found by dividing the voltage across the plates by the separation. If the specimen does not extend all the way from one plate to the other, the field intensity will not be uniform throughout the specimen. However, if the air gap is small compared to the thickness and the transverse dimensions of the specimen, the field intensity will be approximately uniform. In this case we may calculate the field intensity applied to a specimen of low conductivity by using "reluctances" in the same way as in a magnetic circuit. The voltage applied to the specimen will be

$$V_s = \frac{\frac{t_s}{\epsilon_s}}{\frac{t_a}{\epsilon_a} + \frac{t_s}{\epsilon_s}} V \qquad (1)$$

where V is the voltage across the plates,
t_s is the thickness of the specimen,
t_a is the thickness of the air gap,
ϵ_s is the dielectric constant of the specimen, and
ϵ_a is the dielectric constant of the air.

Taking the dielectric constant of the air as unity, and dividing (1) by t_s, the field intensity applied to the specimen will be

$$E_s = \frac{\frac{1}{\epsilon_s}}{t_a + \frac{t_s}{\epsilon_s}} . \qquad (2)$$

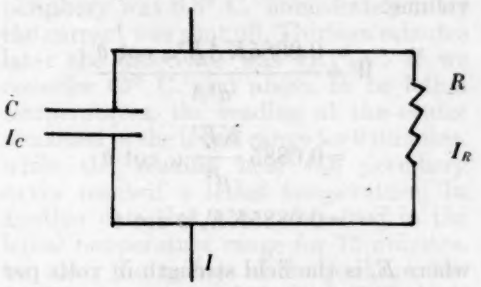
If there are several layers of material between the plates, the individual "reluctances" must be taken into account in an analogous way.

It will be observed that if t_a is very large compared to t_s/ϵ_s, the value of E_s will largely be determined by t_a and ϵ_s. That is, the field applied to the specimen will be almost independent of the thickness of the specimen. Doubling t_a will approximately halve E_s, and so on. However, it must be remembered that our method of "reluctances" does not apply if t_a is comparable to the thickness of the specimen.

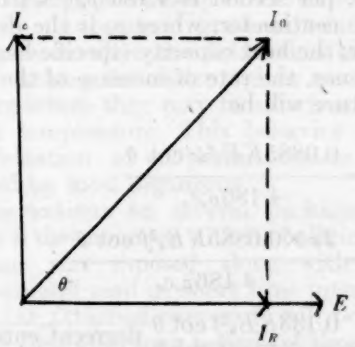
Since the presence of insects causes non-homogeneity in the specimen, the field applied to the insects is not known, but the effect on the field applied to the package is negligible if only a few insects are present.

The rate of increase of the temperature of the specimen can be approximately calculated as shown below.

The load may be regarded as consisting of a condenser in parallel with a resistance R. The capacitance C of the condenser depends on the dielectric constant K of the specimen.



The vector diagram indicates the phase relations between the various currents and the applied voltage.



The power W expended in this circuit is $EI \cos\theta$ watts, where E is the applied voltage and I is the resulting current.

The power factor is cos θ.

$$EI\cos\theta=\frac{EI\,I^2-E^2\omega^2C^2}{I}$$

$$=EI^2-E^2\omega^2C^2$$

$$I^2-E^2\omega^2C^2=E\omega C\cot\theta$$

$$\therefore\ W=E^2\omega C\cot\theta$$

$\omega=2\pi f$, where f is the frequency

For a parallel-plate condenser, with dimensions in centimeters, the capacitance is given by

$$C=0.0885\frac{KA}{d}\text{ farads,}$$

where A is the area of the plates and d is the separation.

$$W=0.0885\frac{KAE^2\omega\cot\theta}{d}.$$

The power input per cubic centimeter, W_s, is obtained by dividing W by Ad, the volume.

$$W=\frac{0.0885KAE^2\omega\cot\theta}{d^2A}$$

$$=0.0885\frac{KE^2}{d^2}\omega\cot\theta$$

$$=0.0885KE_s^2\omega\cot\theta$$

where E_s is the field strength in volts per centimeter.

The power input required to cause the temperature to increase at the rate of 1° C. per second is 4.186 $\rho_s c_s$ watts per cubic centimeter, where ρ_s is the density and c_s the heat capacity (specific heat).

Hence, the rate of increase of the temperature will be

$$\frac{dT}{dt}=\frac{0.0885KE_s^2\omega\cot\theta}{4.186\rho_s c_s}$$

$$=\frac{2\pi\times0.0885KE_s^2f\cot\theta}{4.186\rho_s c_s}$$

$$=\frac{0.133KE_s^2f\cot\theta}{\rho_s c_s}\text{ degrees Centigrade per second.}$$

Since we do not know the values of all the parameters involved, for simplicity we define

$$\alpha=\frac{0.133Kf\cot\theta}{\rho_s c_s}\qquad(3)$$

so that

$$\frac{dT}{dt}=\alpha E_s^2.\qquad(4)$$

We may determine α from $\alpha=(1/E_s^2)(dT/dt)$ and the curves of T as a function of t. For most materials α varies only slightly with temperature and can be considered constant for the insect infested flour employed in this work.

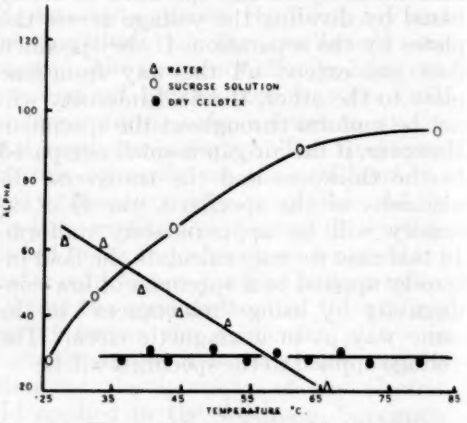


FIG. 1.—The variation of α with temperature. Note that α remains constant for dry celotex, and seems to be approaching a constant for the sucrose solution.

There is a considerable variation in α for different materials and even for different samples of the same material (Fig. 1). The value of α for a specimen containing water depends very much on the amount of water present. In our experiments with liquid specimens with an air gap, the percentage changes in α are more reliable than the absolute values of α, and it will be seen that α may either increase or decrease with temperature. If the heating curve (T plotted as a function of t) is concave upward, α increases with temperature. In the absence of appreciable heat losses, a downward concavity indicates that α decreases with the temperature.

When a specimen is heated in an elec-

tric field, the time rate of increase of the thermometer reading is low for a very short period due to the lag in the thermometer, and then remains fairly constant. When the field is removed, the thermometer reading continues to increase for a short time due again to a lag in the thermometer. After reaching a maximum the temperature of the specimen begins to fall, and the rate of decrease of temperature becomes fairly uniform (Fig. 2).

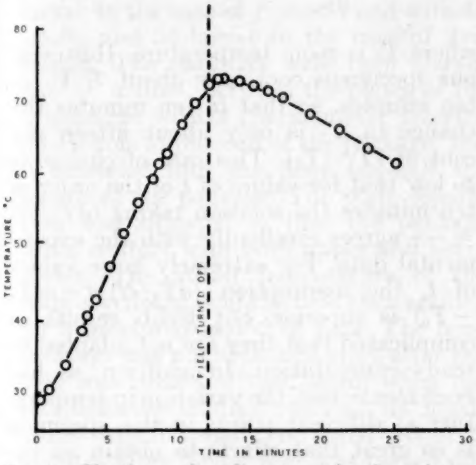


FIG. 2.—Heating and cooling curve for dry celotex under influence of the high frequency field.

For very long periods of time the rate of temperature fall decreases; in fact, the fall of temperature is exponential in agreement with Newton's law of cooling.

When the specimen is heated rapidly, there is not time enough for much heat to be lost to the air, so that while the specimen is being heated there is not much difference between the temperature of the center of the specimen and the temperature of the periphery. However, when the specimen is heated slowly, the rate of heat loss from the surface is so much greater than the rate of heat loss from the center that the periphery cools more rapidly than the center. In either case, after the field is removed, the outer region remains cooler than the inner (Fig. 3). It is therefore possible for a package to attain a lethal temperature only at the center and not at the periphery. Since the insects are distributed throughout the package, it can be seen that the percentage kill may not reach 100 per cent if the center of the package barely reaches, or is just over, a lethal temperature of 65° C. Cooling of the outside makes it necessary to increase the maximum inside temperature to over 70° C. in order to insure complete sterilization of the packaged flour. However, in the case of a two-pound package of flour the

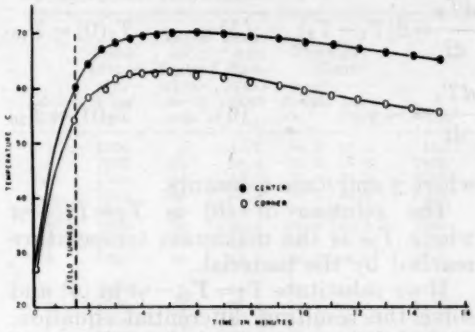


FIG. 3.—Differences in temperature between the corner and center of a flour package heated by the high frequency field.

difference between the maximum thermometer readings of the center and the periphery was 6.3° C. immediately after the current was shut off. Thirteen minutes later the difference was 11.1° C. If we consider 65° C. and above to be lethal temperatures, the reading at the center remained in the lethal range for 9 minutes, while the reading near the periphery never reached a lethal temperature. In another case the center remained in the lethal temperature range for 13 minutes, but near the surface of the package, the reading never exceeded 62.7° C. Even if all the insects are originally at the center of the flour package when the field is applied, they have been observed to follow the temperature gradient which is set up soon after the field takes effect, thus reaching the cooler regions near the surface where they may be safe from the lethal temperature. This behavior is a manifestation of a thermotropism expressed by most organisms.

Observations on several packages in which a thermometer with its bulb in the package was exposed along with the package and read at short time intervals yield the attached curves. It will be observed that after long periods of time the cooling curves become approximately linear.

If we assume that the rate at which the reading t_2 of the thermometer increases is proportional to the difference between the actual temperature T_1 of the material and T_2, and that the material cools so that its temperature after the field is removed falls at a constant rate, we may write

$$\frac{dT_2}{dt}=\beta(T_1-T_2) \qquad (5) \qquad T_1(0)=T_{10}$$

$$\frac{dT_1}{dt}=-\gamma \qquad (6) \qquad T_2(0)=T_{20}$$

where γ and β are constants.

The solution of (6) is $T_1=T_{10}-\gamma t$ where T_{10} is the maximum temperature reached by the material.

If we substitute $T_1=T_{10}-\gamma t$ in (5) and solve the resulting differential equation, we find that

$$T_2=T_{10}+\frac{\gamma}{\beta}-\gamma t + \left(T_{20}-T_{10}-\frac{\gamma}{\beta}\right)e^{-\beta t} \qquad (7)$$

or

$$T_2-T_1=\frac{\gamma}{\beta}+\left(T_{20}-T_{10}-\frac{\gamma}{\beta}\right)e^{-\beta t}$$

where T_{20} is the maximum reading of the thermometer. This means that for large values of the time, T_2 exceeds T_1 by γ/β, since $e^{-\beta t}$ approaches zero.

It may be shown from this equation, and it is also clear from physical considerations, that when T_2 is a maximum, $T_2=T_1$.
That is, when

$$\frac{dT_2}{dt}=0, \qquad T_2=T_1$$

or the curve $T_1=T_{10}-\gamma t$ passes through the point $T_{2\max}$.

We are primarily interested in T_{10}. Since $(dT_1/dt)=-\gamma$, and since $(dT_2/dt)=-\gamma$ *for large* t, as may be shown by differentiating (7) with respect to t, and letting t become large, and since the line $T_1=T_{10}-\gamma t$ passes through the point $T_{2\max.}$, we may locate T_{10} by drawing a straight line parallel to the straight part of the T_2 curve and passing through $T_{2\max.}$. T_{10} is the value of T at which the line $t=0$ cuts this line. For all this work t must be measured from the time at which the Megatherm is turned off.

Objection may be made to our assumption that $(dT_1/dt)=-\gamma$ on the ground that a body actually cools according to the law

$$\frac{dT_1}{dt}=-a(T_1-T_0),$$

where T_0 is room temperature. However, our specimens cool only about 7° C. in ten minutes, so that in ten minutes the change in T_1 is only about fifteen per cent of (T_1-T_0). This rate of change is so low that for values of t of the order of ten minutes the solution taking $(dT_1/dt)=-\gamma$ agrees excellently with the experimental data. For extremely large values of t, the assumption $(dT_1/dt)=-a(T_1-T_0)$ is superior, but yields results so complicated that they are not adapted to ready computation. In addition, as has been mentioned, the variation in temperature at different points in the specimen is so great that efforts to obtain an extremely precise correction are rather pointless (see Fig. 3).

By finding values of γ and β from observed heating curves and calculating T_2 from the solution of the differential equation, it was found that the solution of the differential equations (5) and (6) described the curves observed quite well. The maximum temperature actually reached within the specimen was thus shown to differ from the maximum thermometer reading by considerably less than the difference between the temperature at the center and the temperature at the periphery. Therefore, the maximum reading of the thermometer was taken as the maximum temperature in the package, with negligible error.

In the initial empirical experiments, various sized commercial packages of cereals, some with wax wrappers, others wrapped in cellophane, and all having relatively nonhomogeneous contents, were tried in the field with inconsistent results to be described later. Therefore, a standard package of plain cardboard with dimensions 10×3×7 cm., and containing 140 gms. of a sifted bleached wheat

flour, was chosen in order to eliminate disturbances from the wrappings and nonhomogeneous contents. Two different species of test organisms were used with these packages, *Ephestia kuhniella* larvae, and *Tribolium confusum* adults, pupae and larvae. The packages were prepared by filling with flour, sealing, and introducing the insects through a small hole at one end which was then covered with a piece of masking tape. Each package was inoculated with 25 larvae in the case of *Ephestia* and with 50 adults and 50 larvae in the case of *Tribolium*. The packages were then placed, one at a time, between the plates of the *Megatherm* with a thermometer inserted into a hole at one end of the package, and it extended into the flour one-half the length of the package. The plate separation was adjusted so that the package made contact with both upper and lower plates. The initial temperature of the flour was noted, and the field then applied for a measured period of time. The temperature was noted immediately after the field was turned off and again when the thermometer reading reached its maximum, which usually occurred about 3 minutes after the current was turned off. This last reading, called the "maximum temperature" in the following discussion, was taken to be a close approximation to the actual temperature of the contents of the package. As soon as the maximum temperature was attained, the package was removed from between the plates, the thermometer withdrawn, and the hole sealed. The package was then incubated at 25° C. for one day, at the end of which period the contents were sifted through a number 80 sieve to separate the insects from the flour, and the number of dead insects determined. The insects were retained and incubated for several weeks to determine the validity of the observation that they were dead. The living insects were incubated separately to determine whether the survivors lost the ability to continue development in the case of the larval forms, or whether the adults were affected in regard to fertility or longevity.

The field applied to the packages had a frequency of eleven megacycles per second. The field intensities were varied from 1200 to 1700 volts/cm. Higher fields were tried, but they usually caused arcing and other disturbances to be discussed below.

Table 1 gives the results of applying a field of three different intensities for the indicated periods of time to packages containing the *Tribolium* larvae and adults.

Table 1.—Effects of the high-frequency field on *Tribolium confusum*.

Run No.	Field Intensity volts/cm.	Period of Treatment seconds	Maximum Temperature °C.	Per Cent Dead		tE_s^2
				Adults	Larvae	
1	1350	5	33.1	19.0	20.6	910×10^4
2	1350	10	40.4	31.3	38.6	1820
3	1350	15	50.8	72.6	75.5	2730
4	1360	20	57.4	92.0	98.0	3680
5	1360	25	64.9	92.2	100.0	4600
6	1350	30	68.1	99.0	100.0	5460
7	1360	35	81.5	100.0	100.0	6440
8	1360	40	85.8	100.0	100.0	7360
1	1560	3	32.6	20.0	16.2	729
2	1530	6	39.1	27.8	25.2	1404
3	1540	10	48.9	63.6	73.0	2370
4	1560	13	53.4	93.0	94.0	3159
5	1540	16	59.4	94.8	98.0	3792
6	1540	19	63.3	95.2	100.0	4503
7	1560	22	70.5	98.0	100.0	5346
1	1740	5	41.0	50.0	29.0	1510
2	1760	7	46.5	76.5	53.0	2763
3	1770	10	54.9	88.0	90.0	3130
4	1760	13	63.4	98.0	99.0	4017
5	1790	16	71.0	99.0	100.0	5120
6	1790	18	75.0	100.0	99.0	5760

Each value involved 100 adults and 100 larvae. It has been demonstrated that the constancy of α for the insect infested flour packages is well borne out empirically over the range of temperature tested.

$$\frac{dT}{dt}=\alpha E_s^2. \tag{8}$$

Integrating this equation between limits we get

$$T_2-T_1=\alpha E_s^2(t_2-t_1). \tag{9}$$

Calling the temperature change ΔT, and since the initial time is zero, we get

$$\alpha=\frac{\Delta T}{tE_s^2}. \tag{10}$$

The values given in the last column of table 1 are equivalent to tE_s^2 in equation (10).

Table 2 gives data similar to the data in table 1, except that the packages contained *Ephestia* instead of *Tribolium*.

Figures 4 and 5 present the above described data graphically. It will be noticed from figure 4 that the number of insects

killed is directly correlated with the maximum temperature attained in the packages. The values from the tables for both species of insects fall into a well defined s-shaped curve, indicating that these insects are all equally susceptible to the

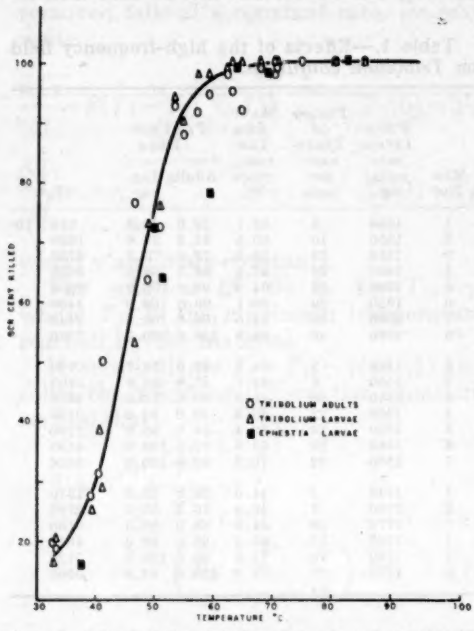


FIG. 4.—The relation of the per cent insects killed to the maximum temperatures attained in the flour packages under the influence of the field.

effects of the field as manifested in the maximum temperature of the flour medium regardless of taxonomic or developmental differences. The number of insects killed bears a straight-line relationship to the temperature between 40° and 50° C., but the temperature rate of kill decreases above 50°, and a 100 per cent kill is obtained for all runs above 70°.

It is generally assumed by insect physiologists that the lethal temperature range for insects starts at about 50° C., and 60° C. is generally considered to be the maximum fatal high temperature (Belehradek, 1935). In other words, death occurs at varying degrees of time between 50° and 60°, but is almost instantaneous above 60°. This is, of course, a generalization which must be tested for specific cases. Therefore, various developmental stages of *Tribolium* were placed in test tubes and the tubes introduced into water baths at various constant temperatures. The results of these tests are given in table 3. The data in this table indicate that at 45° there is no lethal effect after periods of exposure as long as 22 minutes. At 50° there is a lethal effect at 4 minutes, and at 60° and 65° the lethal effect occurs in 30 seconds or less. Exactly how rapidly death does occur at these high temperatures is difficult to determine, but these data correlate well with the data presented in figure 4, from which it will be noted that the 100 per cent lethal effect is incipient at about 60°. The data in figure 4 are at variance with the observation that there was no lethal effect at 45° in the case of externally applied heat, since it can be seen from the graph that between 40 and 50 per cent of the insects were killed at this temperature under the influence of the high-frequency field. However, we must consider

Table 2.—Effects of the high-frequency field on *Ephestia kuhniella*.

Run No.	Field Intensity volts/cm.	Period of Treatment seconds	Maximum Temperature °C.	Per cent Dead Larvae	tE_0^2
1	1253	20	49.9	72.3	3120×10^4
2	1205	30	63.9	99.0	4320
3	1208	35	69.2	98.0	5040
4	1204	40	81.2	100.0	5760
5	1204	50	96.3	100.0	7200
1	1583	5	37.7	17.0	1250
2	1579	10	50.5	63.9	2500
3	1578	15	59.2	78.0	3750
4	1565	20	68.5	100.0	4920
5	1563	25	82.9	100.0	6075

Table 3.—Effects of externally applied heat on *Tribolium confusum*.

Temperature ° C.	Time, Minutes	Per Cent Dead		
		Larvae	Pupae	Adults
45	30.0	0	0	0
50	1.0	0	0	0
	2.0	0	0	0
	3.0	0	0	0
	4.0	72	0	90
	5.0	100	0	100
	6.0	92	75	100
	7.0	100	100	100
	8.0	100	100	100
60	0.5	98	87	81
	1.0	100	100	100
	2.0	100	100	100
65	0.5	100	100	100
	1.0	100	100	100
	2.0	100	100	100

that the temperature was not necessarily uniform throughout the body of the insect, and more closely controlled observations must be made before one may conclude that there is an effect other than temperature under the influence of the field.

It is demonstrated in figure 5 that an increase in the field intensity effects a decrease in the time necessary to kill a given number of *Tribolium* adults and larvae. The data for *Ephestia* are not

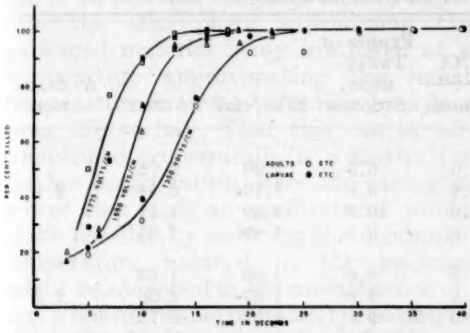


FIG. 5.—The relation between the per cent insects killed (tribolium) and the time the field was applied for three different field intensities.

represented in this graph, but it can be seen from table 2 that this generalization is true for this species as well.

In the previous discussion it was pointed out that

$$\alpha = \frac{\Delta T}{tE_s^2} . \qquad (10)$$

This can be taken as valid in the case of flour if α is a constant over the temperature range under consideration, as is the case for dry celotex (Fig. 1). It is indicated in figure 6, line B, that this is a valid assumption, for line B was derived by plotting the maximum temperature of the flour (which is ΔT+the initial constant temperature of the flour) against the values of tE_s^2. The slope of line B is the value of α for flour, the loss of heat from the specimen being ignored.

Since the rate of rise of temperature in the flour is directly proportional to the square of the field intensity, or considering the integrated form of equation (4), since the increase in temperature is directly proportional to tE_s^2, the relationship between the number of insects killed and the maximum temperature can be more precisely stated. Curve *A*, figure 6, was derived by plotting the percentage of insects killed against tE_s^2. This is an s-shaped curve with a straight-line portion between 1500 and 3800 volts^2 sec./cm.^{2}. Above and below these values the curve turns off to parallel the *X*-axis, since the field has a maximal and minimal lethal effect on a given number of insects. Curve *A* demonstrates further that in the range indicated, the number of insects killed is related to tE_s^2, which is in turn directly proportional to the increase in temperature. It has already been demonstrated that the number of insects killed is directly proportional to the increase in temperature (Fig. 4). It may then be concluded that the number of insects killed above ca. 40° C. and below the maximum lethal temperature, 65° C., is directly proportional to the maximum temperatures attained in the flour under the influence of the field. Figure 5 is a qualitative demonstration of the fact shown in curve *B* of figure 6 that the time required for 100 per cent mortality is inversely proportional to the square of the applied field intensity.

The insects treated in the field as described above were examined one month

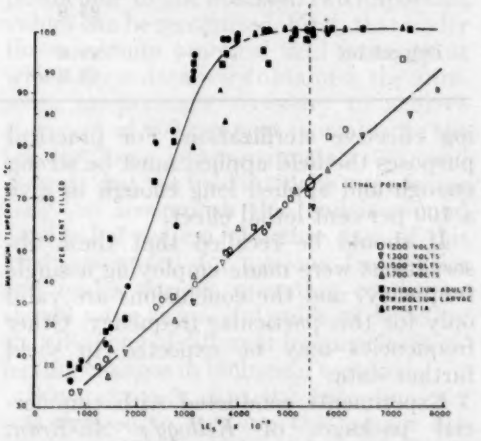


FIG. 6.—A. The relation between the per cent insects killed and tE_s^2. B. The relation between the maximum temperature of the flour and tE_s^2.

after treatment, and it was found that those individuals which had survived the effects of the field up to the time of the first examination of the package contents had continued to survive for the ensuing month. Furthermore, the adults had laid fertile eggs and the larval and

pupal forms had completed development to adults. These data indicate that the fields applied do not have an appreciable debilitating effect on the surviving insects which would cause them to lose their capabilities to continue development or reproduction. It is possible that the field is capable of causing partial injury without ensuing death, but it is evident that any partial injuries which do occur cannot be relied upon as a means of attaining effective sterilization. For practical purposes the field applied must be strong enough and applied long enough to give a 100 per cent lethal effect.

It should be recalled that these observations were made employing a single frequency, and the conclusions are valid only for this particular frequency. Other frequencies may be expected to yield further data.

Experiments conducted with commercial packages of *Kellogg's All-Bran, Nabisco 100 per cent Bran, Grape Nuts Wheat Meal,* and black-eyed peas gave anomalous results. In most cases arcing resulted before the lethal temperature was attained, and the temperature maxima did not increase linearly with the exposure periods as they did in the case of the flour. Furthermore, the killing effect was not consistent for the various periods of exposure. These results may be explained in part by arcing through the wax wrappers on the packages. Another reason for the inconsistent killing results may be that the media were quite nonhomogeneous compared with the flour, and, as has been pointed out above, a uniform field cannot be expected in a heterogeneous medium (Baker & Madsen, 1945).

When arcing occurs to some point on or inside the package, either the packaging material or the contents are charred. In the case of the sifted flour, the material was not affected until temperatures over 80° C. were attained, when the flour apparently began to glutinize. Only in the case of the flour could 100 per cent mortality be attained without damaging the contents of the package or the package itself.

It might be suggested at this point that the source of the high-frequency field should have provision for varying the frequency. Such a modification would facilitate the use of the apparatus for experimental purposes. A provision for continuous adjustment of the feedback while the apparatus is in operation would adapt it better to both research and commercial uses. It should be possible to vary the coupling between the tank circuit and the load, since some specimens overload the oscillator. Variable coupling would

Table 4.—Values of alpha for different materials.

Material	Weight, Ounces	Temperature °C. Initial	Temperature °C. Maximum	Period of Treatment, Seconds	E(kv/cm)	Alpha	Average Alpha
Grape-Nuts Wheat meal	16	26.8	52.0	6.5	1.20	2.72	
		26.5	46.2	5.8	1.16	2.54	2.4
		26.3	60.0	10.0	1.49	1.51	
		26.0	83.0	9.0	1.49	2.84	
Nabisco 100% Bran	16	25.3	41.8	9.0	1.06	1.63	
		25.0	64.8	9.0	1.37	2.36	2.2
		25.0	71.0	9.0	1.37	2.73	
Kellogg's All-Bran	16	25.0	32.8	9.0	1.13	0.677	
		24.6	37.0	12.2	1.12	0.809	0.73
		24.5	44.7	19.0	1.23	0.702	
Flour	—	26.0	96.5	35.0	1.56	0.825	
		26.3	96.2	30.0	1.62	0.889	0.88
		25.8	94.5	30.0	1.56	0.942	
Dry celotex	—	24.6	85.0	405.0	0.708	0.295	0.31
		28.7	73.0	720.0	0.441	0.316	

make it possible to maintain constant voltage over a wide range of operating conditions (Mittelmann 1945).

From the experiments reported here, it has become quite evident that the loss of heat from the surface of materials irradiated in an electric field necessitates the induction of higher temperatures in the center of the mass to accomplish a 100 per cent lethal effect throughout the mass than would be required if the heat losses were reduced. This suggests the use of an external source of heat to maintain the atmosphere surrounding the packaged material being irradiated at a temperature approximating the lethal temperature in order to reduce heat loss from the surface. That this can be accomplished economically is a matter for further investigation, since the saving in power that such an arrangement would make possible by reducing the maximum temperature induced in the package might be absorbed in the maintenance of, say, a hot air tunnel in which the packages are treated. However, the advantages gained in time and consequent increased production rate might well warrant such a practice. Also, the lower internal temperature required might be desirable in the case of materials readily damaged by high temperature.

All measurements of temperature reported here were made by means of a mercurial thermometer, and consequently represent the approximate temperature of the medium in which the insect was irradiated and not necessarily that of the insect itself. Therefore, temperature effects considered here may represent merely the secondary influence of the radiated or conducted heat of the flour, and may not be considered of a primary order of significance, such as the internal temperature of the insect. In this respect investigations of the fundamental physiological influences of high-frequency electric fields should be undertaken to aid in the interpretation of the causes of death. A correlation between oxygen uptake of insects under controlled water bath temperatures and during irradiation would serve as an indication of induced internal temperatures in the insects under the influence of the high-frequency electric field. The measurement of metabolic activity of irradiated insects by means of respiratory rates has been attempted employing the Summerson respirometer for measuring oxygen uptake with continuously increasing temperature. However, differential manometric measurements did not prove well adapted to this purpose and were abandoned.

That there exists a primary effect of the field on the insects has been the premise upon which much of this research is predicated. This being the case, it is suggested that the value α be determined for insects in various stages of development and of various taxonomic groups, and further that specific tissues be evaluated in terms of their response to high-frequency electric fields. It is indicated from the experiments reported here that α may not be a constant, but may vary as the inherent physical organization of the specimen is modified by the effects of the field. An investigation of the α of insects and insect tissues may lead to a clearer evaluation of the lethal effect as well as a more efficient practical procedure for sterilization.

A careful consideration of figure 6 and the discussion in the text will indicate several points of practical significance. It can be seen that by dropping a line from the earliest point of 100 per cent mortality on curve A to intersect curve B and fall perpendicular to the abscissa, two important values can be recognized. First, that under the maximum practical field intensity at which these data were obtained, the minimum temperature necessary to achieve the point of 100 per cent mortality in the shortest time is approximately 70°, and second, that the field intensity time factor (tE_s^2) to accomplish this end is around 5400 volts^2 sec/cm.^{2} Further data of this kind assembled for various frequencies and under various operating conditions should serve as a useful guide in detecting the efficiency of different frequencies in effecting changes in biological materials.

SUMMARY.—A capacity potentiometer was devised to measure the voltage applied across the condenser plates of a high-frequency electric generator.

A mathematical evaluation of the field intensity applied to the specimen is presented.

The lethal effect of high-frequency electric fields on insects in various media was measured, and a correlation between temperature, time, field intensity, and mortality is presented.—4-5-46.

BIBLIOGRAPHY

Ark, P. A. and Willer Parry. 1940. Application of High-frequency electrostatic fields in agriculture. *Quarterly Review of Biology* **15**: 172–91.

d'Arsonval, A. 1893. Influence de la fréquence sur les effets physiologiques des courants alternatifs. *Compt. Rend. Acad. Sci.* (Paris), **116**: 630–2.

d'Arsonval, A. 1893. L'auto conduction ou nouvelle méthode d'électrisation des êtres vivants: mesure des champs magnétiques de grande fréquence. *Compt. Rend. Acad. Sci.* (Paris), **117**: 34–6.

d'Arsonval, A., and M. Charrin, 1896. Action des diverses modalités électriques sur les toxines bacteriennes. *Compt. Rend. Soc. Biol.* **48**: 96–9.

d'Arsonval, A., and M. Charrin. 1896. Action de l'électricité sur les toxines bacteriennes. *Compt. Rend. Soc. Biol.* **48**: 121–3.

Baker, R. M., and C. J. Madsen. 1945. High frequency heating of conductors and non-conductors. *Proceedings of the National Electronics Conference.* **1**: 360–80.

Belehradek, J. 1935. Temperature and Living Matter. Gebruder Borntraeger.

Duggar, Benjamin M. 1936. *Biological Effects of Radiation*, Vol. **1**: 541.

Hadjinicolaou, J. 1931. Effects of certain radio waves on insects affecting certain stored products. *Jour. New York Ent. Soc.* **39**: 145–60.

Headlee, Thomas J. 1931. The differential between the effect of radio waves on insects and on plants. JOUR. ECON. ENT. **24**(2): 427–37.

Headlee, Thomas J. 1932. Further studies of the effects of electromagnet waves on insects. JOUR. ECON. ENT. **25**(2): 276–88.

Headlee, Thomas J. 1933. The effects of radio waves on the internal temperatures of certain insects. JOUR. ECON. ENT. **26**(2): 313–9.

Headlee, Thomas J. 1934. Some observations on the effect of radio waves on insects and plant hosts. *New Jersey Agr. Exp. Sta. Bul.*, 568–83.

Headlee, Thomas J., and R. C. Burdette. 1929. Some facts relative to the effect of high-frequency radio waves on insect activity. *Jour. N. Y. Ent. Soc.* **37**: 59–64.

Headlee, Thomas J., and D. Manley Jobbins. 1936. Further studies of the use of radio waves in insect control. JOUR. ECON. ENT. **29**(1): 182–7.

McKinley, G. M. 1930. Some biological effects of high-frequency electrostatic fields. *Proceed. Penn. Acad. Sci.* **4**: 43–6.

McKinley, G. M., and D. R. Charles. 1930. Certain biological effects of high-frequency fields. *Science* **71**(1845): 490.

Mittelmann, E. 1945. New Methods and Techniques in High Frequency Heating. *Proc. Nat'l Electronics Co ference* **1**: 392–406.

Schereshewsky, J. W. 1926. The physiological effects of currents of very high frequency (135,000,000 to 8,300,000 cycles per second). *Public Health Rpts.* **41**: 1939–63.

Schereshewsky, J. W. 1933. Heating effects of very high-frequency condenser fields on organic fluids and tissues. *Public Health Rpts.* **48**: 844–58.

Schereshewsky, J. W. 1933. Biological effects of very high-frequency electromagnetic radiation. *Radiology* **20**: 246–53.

Schereshewsky, J. W., and H. B. Andervont. 1928. The action of currents of very high frequency upon tissue cells. A. Upon a transplantable mouse sarcoma. B. Upon a transplantable fowl sarcoma. *Public Health Rpts.* **43**: 927–45.

Schliephake, E. 1928. Die biologische Wärmewirkung im elektrischen Hochfrequenzfeld. *Deutsch. Gesellschaft für innere Med.* **40**: 307–10.

INSECT MICROBIOLOGY. By Edward A. Steinhaus, University of California, Berkeley, California. 763 pages, 250 figures. 1946. Comstock Publ. Co., Ithaca, N. Y. Price $7.75.

Insect Microbiology by E. A. Steinhaus presents the known biologic relationships existing between insects and microorganisms. It is an authoritative and a well documented book. Many unique and important facts are presented on the role insects and ticks play relating directly or indirectly to the health and economic welfare of man. Not only are large numbers of facts assembled but they are so correlated as to make this work an outstanding contribution in the field of microbiology.

The contents includes an extensive presentation of the known facts on extracellular and specific bacteria associated with insects. There are also complete compilations and contributions on the intracellular bacteriumlike and Rickettsia-like symbiots, Rickettsiae and spirochetes associated with insects and ticks. Other chapters discuss yeasts, fungi, protozoa and viruses found among insects. Chapters on "Immunity in Insects" and "Methods and Procedures" are worthwhile additions. At the end of the book occurs an extensive bibliography and a complete index invaluable in a book of this type. The author carefully refers all citations throughout the text to the bibliography.

The book will be of decided value to entomologists interested in biological control, disease transmission or physiology. It contains a great deal of information which will be new to many entomologists. It should prove to be a valuable reference volume for many biological scientists, especially bacteriologists, research physicians, and veterinarians. This book covers a border line field and demonstrates clearly the interrelatedness of closely allied sciences. It should help to bring biological scientists in several fields closer together in their research efforts.

Dr. Steinhaus, primarily a bacteriologist, has treated the entomological facts in a satisfactory manner. With few exceptions a "dyed in the wool" entomologist could not have done better. Congratulations to the author!—ALVAH PETERSON.

The Application of Measured Amounts of Petroleum Spray Oils to Individual Olive Scales

E. M. Stafford, *California Agricultural Experiment Station, Davis*

In the course of investigations to determine control measures for the olive scale, *Parlatoria oleae* (Colvée), it was found that the continued use of medium to heavy petroleum spray oils (40 to 10 per cent by volume distillling at 636° F.) resulted in reduced yields of olives. Light oil (64 to 79 per cent by volume distilling at 636° F.), though showing no apparent deleterious effects on olive trees, gave very poor control of the olive scale. The object of the work reported here was to study the increase in effectiveness of light summer oil in controlling the olive scale by the addition of toicants to the oil.

Equipment and Methods.—The crawlers of the olive scale usually settle close together, especially along the midribs of olive leaves and leaves of other host plants. The result is crowding and frequent overlapping of the adult scales. Contributing further to this crowding is the tendency of many crawlers to settle beneath the parent shell. Live scales are often found beneath, and surrounded by, old shells of past scale generations. Since each scale shell retains some of the oil deposited from an oil spray, obviously the amount of oil needed to kill all the scale in a crowded infestation is greater than the amount needed where the infestation is uniformly scattered. To avoid variations in kill due to the crowding, it was decided to apply measured amounts of oils or oil-toxicants directly to individual scales by means of a micropipette. For the sake of obtaining as uniform test insects as possible, only non-ovipositing adult female scales were used. Such scales were found on Japanese privet leaves in January, February, and March.

The experimental procedure was to collect scaly leaves, wash them with tap water, and allow them to remain overnight with their petioles in water. Then scales were selected for size, age, and distance from other scales on the leaf. Only those separated from each other by twice their diameter were chosen. The selected scales were numbered, and their outlines were traced by means of a camera lucida. The leaf area covered by each scale was estimated by determining the area of the tracings and reducing them by a calculation that nullified the microscope magnification. The leaf areas covered by the scales ranged from 0.6 to 1.6 square millimeters.

Smith (1938) developed a microtechnique by which he applied very small quantities of oil or other material to the spiracles of the citrus red scale. The amounts, however, were not measured. McGovern (1941) and others designed a very ingenious micropipette for applying insecticides to individual insects. This pipette, however, did not deliver small enough volumes for use with individual scale insects. Even the microburette of Scholander (1942) delivers volumes too large for work with individual olive scales.

The micropipettes used in the present work consisted of fine glass capillaries. These capillaries had a diameter of about 0.05 mm., and each was calibrated by drawing oil from a larger capillary (0.172 mm. in diameter) and measuring the length of small capillary the oil occupied. The volume of oil in the smaller capillary was calculated from the measured reduction in volume of the oil in the larger. The calibrations were made after the walls of the small capillary had been wet with oil. Varying the viscosity of the oil made no difference in the calibration, but greatly affected the time necessary to drain the small capillary. Measurements were made under a binocular microscope fitted with a micrometer eyepiece. The micropipette was amounted on a mechanical manipulator. In filling the micropipette with the desired volume of oil, the operator had to attain a delicate slight contact between the point of the pipette and the opening of the larger capillary that served as a reservoir. With too close a contact the oil from the larger capillary would rush into the micropipette with uncontrollable speed. When the micropipette was filled to the desired length, the contact was broken by moving the larger capillary, which was mounted on a glass slide clipped to the mechanical stage of the microscope.

In applying the oils, the tip of the mi-

cropipette was placed in contact with the approximate center of the scale shell and allowed to drain. When the position of the scale on the leaf made good contact with the micropipette difficult, the flow of oil from the micropipette sometimes had to be initiated by air pressure applied at the opposite end of the glass capillary. Dosages were expressed in terms of 10^{-6} cc. per mm.^{2} of leaf surface covered by the scale.

After the scale had been oiled, the leaves were placed with their petioles in water in a constant-temperature cabinet at 25° C. and about 88 per cent relative humidity. After 10 to 14 days a microscopic examination was made to determine the numbers of live and dead scales.

Table 1.—Area of base, height, and estimated volume of scale shells.

Scale No.	Height mm.	Area mm.^{2}	Volume mm.^{3}	Volume/ Area
1.	0.25	2.26	0.183	0.083
2.	0.25	2.11	0.176	0.083
3.	0.25	1.71	0.142	0.083
4.	0.25	1.87	0.156	0.083
5.	0.24	1.71	0.137	0.080
6.	0.21	1.62	0.118	0.070
7.	0.21	1.25	0.087	0.069
8.	0.17	1.13	0.075	0.066
9.	0.21	0.98	0.069	0.070
10.	0.12	0.46	0.018	0.039

EXPERIMENTAL RESULTS AND DISCUSSION.—The question naturally arises, should the dose be measured by the leaf area which the scale covers or by the volume of the scale shell? In an attempt to estimate roughly the volume of the shell, ten scale shells were carefully removed from a leaf and fixed to a glass slide with a very thin film of glycerine. The areas were determined as outlined above, and the heights were measured. Assuming the area to be a circle and the shape of the shell that of a right cone, the volume was calculated. Table 1 gives the results. Though the shell was certainly not shaped like a right cone, the estimated volumes tended to be closely related to the area of the leaf covered by the scale. In any case, subsequent results showed that among scales treated the same day with the same oil there was no marked relation between scale size (as determined by area of the leaf covered) and the dosage necessary to kill.

In 1943 three oils were tested alone and with rotenone. The first was light summer oil of 92.4 per cent unsulfonated residue, 64.5 Saybolt viscosity at 100° F., 65.0 per cent distilling at 636° F.; the second was medium summer oil of 92.1 per cent unsulfonated residue, 80.9 Saybolt viscosity at 100° F., 45.0 per cent distilling at 636° F.; and the third was heavy summer oil of 93.6 per cent unsulfonated residue, 101.0 Saybolt viscosity at 100° F., 23.0 per cent distilling at 636° F. Rotenone was dissolved in the oil by using 11.0 per cent by weight of a mutual solvent (3,5,5, trimethyl cyclohexene-2-one-1) and derris resins (30 per cent rotenone) to give 0.06 per cent rotenone in the oil. Table 2 summarizes the results of the treatments. In this table the median lethal dosage (M.L.D.) was calculated by the method of Campbell & Filmer (1929). The toxicity of all the oils was increased by the addition of rotenone, the increase being greatest for the light oil. The addition of the solvent to the medium oil decreased its toxicity. Without oil, the mutual solvent and rotenone showed no toxicity at the dosages used. This lack of toxicity may have resulted from the very low viscosity of the mutual solvent. A count of 443 selected but untreated scales showed only 0.9 per cent dead.

For a comparison with the micropipette studies, a series of laboratory sprays were applied to infested Japanese privet leaves, oils being the same as those mentioned above. Leaves were sprayed very thoroughly. To keep the oil deposit low, *Vatsol OT* (3 ounces per 100 gallons) was used for all treatments. The results (summarized in table 3) showed the same trends as the results of the micropipette studies. The light oil containing rotenone gave somewhat lower results than might have been expected from the micropipette studies.

In 1944, with the micropipette technique, several materials were tested for their effectiveness in increasing the toxicity of light summer oil to adult female olive parlatoria scales. In these tests a dosage of 1.00×10^{-6} cc. per square millimeter was used throughout. This dose was selected because it was well within the sublethal dosage range. To kill the insects, any increase in effectiveness caused by the addition of a toxicant to the oil would therefore have to be large. Since the intermediate dosage range for

Table 2.—The toxicity of petroleum spray oils, alone and with rotenone,[1] to adult female olive parlatoria scales.

Treatment	Lethal Dosage Range[2]	Intermediate Range		Sublethal Dosage Range[2]	M.L.D.[2]
		Dosage Range[2]	Number of Scales		
1. Light oil	3.20– —	1.85–3.00	21	1.51–1.81	2.3
2. Light oil, 11% mutual solvent, 0.06% rotenone	0.91–4.00	0.50–0.80	9	0.25– —	0.7
3. Medium oil	2.22–3.34	1.52–2.00	9	1.25–1.48	1.8
4. Medium oil, 11% mutual solvent, 0.05% rotenone	1.22–3.00	0.52–1.21	6	0.25– —	0.7
5. Heavy summer oil	1.91–3.91	1.25–1.88	10	1.20– —	1.6
6. Heavy oil, 11% mutual solvent, 0.06% rotenone	0.74–2.83	—	—	0.51–0.73	—
7. Medium oil and 11% mutual solvent	2.75–3.57	1.48–2.75	18	0.50–1.25	2.5
8. Mutual solvent, 0.06% rotenone	—	—	—	0.25–3.00	—

[1] Derris resins (30 per cent rotenone) were dissolved in oil by the use of 11 per cent, by weight, of a mutual solvent, 3,5,5, trimethyl cyclohexene-2-one-1.
[2] All dosages in terms of 10^{-6} cc. per mm.^{2} of leaf surface covered by the scale.

the light summer oil was 1.85 to 3.00 $\times 10^{-6}$ cc. per mm.^{2}, an increase in effectiveness due to the presence of a toxicant would not be expected to appear unless it was equivalent to an 85 percent increase in dosage of base oil alone. Table 4 summarizes results of the tests. In the course of the experiment, 753 selected adult female scales were held untreated in the constant-temperature cabinet. They were examined at the same time with scales that had been chosen and oil treated on the same day. Of the untreated scale only 2, or 0.265 per cent were found dead on examination.

It was somewhat surprising that oil containing nicotine showed no increase in toxicity. In oil-nicotine emulsions most of the nicotine enters the aqueous phase, so that the amount coming into contact with a sprayed scale insect is both small and dilute. Where oil-nicotine alone was applied with a micropipette to avoid the loss of nicotine from the oil by its dispersion into an aqueous phase (Norton 1940), the effectiveness of the oil was not measurably increased. Oil containing DDT also showed but little increase in toxicity at the concentrations of DDT used.

The addition of rotenone increased toxicity in all cases. On the basis of rotenone content, preparations containing cube root were more toxic than those containing derris resins. The explanation may be the presence of other toxicants in the cube root, or the physical and chemical nature of the derris resin preparations brought about by the solubilizer, *Isophorone*.

An apparent synergism of petroleum oil extractives of cube root and *Velsicol AR-60* was noted. Light summer oil containing 0.06 per cent rotenone from

Table 3.—Toxicity of petroleum spray oil emulsion, with and without rotenone,[1] to adult female olive parlatoria scales.

Treatment	Number Counted	Per Cent Dead
1. Light summer oil; 2 per cent	188	2.6
2. Light oil containing 11% mutual solvent and 0.06% rotenone; 2 per cent	164	55.5
3. Medium summer oil; 2 per cent	226	23.9
4. Medium oil containing 11% mutual solvent and 0.06% rotenone; 2 per cent	136	77.2
5. Heavy summer oil; 2 per cent	323	41.1
6. Heavy oil containing 11% mutual solvent and 0.06% rotenone; 2 per cent	244	74.1
7. Medium oil containing 11% mutual solvent; 2 per cent	215	19.0
8. Mutual solvent containing 0.06% rotenone; 3 per cent	84	0.0
9. Untreated	102	0.9

[1] Derris resins (30 per cent rotenone) were dissolved in the oil by the use of 11 per cent by weight of a mutual solvent, 3,5,5, trimethyl cyclohexene-2-one-1.

Table 4.—The toxicity of light summer oil, alone and with toxicants added,[1] to adult female olive scales at a dosage of 1.00×10^{-6} cc. permm.[2] of leaf surface covered by the scale.

Treatment—Per Cent Toxicant in Oil[1]	Number Treated	Per Cent Dead
1. Light oil alone	19	0.0
2. Triamylamine 1.0%	22	4.6
3. Triamylamine 2.0%	10	0.0
4. Triamylamine 4.0%	10	0.0
5. Lethane 60[3] 2.0%	10	0.0
6. *Lethane 60* 4.0%	10	0.0
7. 1,1, dichloro-1 nitroethane 1.0%	10	0.0
8. nicotine alkaloid[3] 1.0%	20	0.0
9. nicotine alkaloid 2.0%	10	10.0
10. nicotine alkaloid 4.0%	10	0.0
11. DDT[4] 1.0%	20	0.0
12. DDT 2.0%	10	10.0
13. Vatsol OT[5] 0.5%, Butyl *carbitol*[6] 0.2%	18	11.1
14. Ground cube root (4.3% rotenone) to supply 0.06% rotenone in treatment 13[7]	19	67.3
15. Ground cube root (4.3% rotenone) to supply 0.12% rotenone in treatment 13	10	100.0
16. Mutual solvent 6.5%,[8] derris resins (30% rotenone) to supply 0.06% rotenone[9]	20	50.0
17. Mutual solvent 10.0%, derris resins (30% rotenone) to supply 0.06% rotenone[10]	10	60.0
18. Mutual solvent 12.0%, derris resins (30% rotenone) to supply 0.06% rotenone	20	35.0
19. Mutual solvent 15.0%, derris resins (30% rotenone) to supply 0.12% rotenone	10	90.0
20. Ground cube root (4.3% rotenone) to supply 0.06 rotenone[7]	20	75.0
21. Ground cube root (4.3% rotenone) to supply 0.12% rotenone	10	100.0
22. *Velsicol AR-60*[11] 1.0%	20	5.0
23. *Velsicol AR-60* 2.0%	10	20.0
24. *Velsicol AR-60* 1.0%, ground cube root (4.3% rotenone) to supply 0.06 rotenone	20	100.0
25. *Velsicol AR-60* 0.5%, ground cube root (4.3% rotenone) to supply 0.03% rotenone	10	100.0

[1] Per cent by weight.
[2] An insecticide containing not less than 50 per cent by volume of beta-thiocyano ethyl esters of fatty acids with 10 to 18 carbon atoms.
[3] Source of nicotine was *Black leaf 40*. NaOH was added to oil and *Black leaf* 40 to make the aqueous phase approximately 5.5N.
[4] 1 trichloro-2,2-bis (p-chlorophenyl)-ethane, technical grade; source, Geigy Company, Inc.
[5] Dioctyl sodium sulfosuccinate.
[6] Diethylene glycol monbutyl ether.
[7] Ground root and oil shaken for 20 minutes. Used clear liquid after powder settled.
[8] 3,5,5 trimethyl cyclo hexene-2-one-1.
[9] Not sufficient solvent to make resins completely soluble in oil.
[10] Oil slightly cloudy.
[11] Methyl naphthalenes.

ground cube root (4.3 per cent rotenone) killed 75 per cent of the scale treated. Light summer oil containing 1 per cent *Velsicol AR-60* killed 5 per cent of the scales. When light summer oil containing 0.03 per cent rotenone from ground cube root and 0.5 per cent *Velsicol AR-60* was used, all the insects treated were killed.

Apparently the method employed was sensitive enough to be used as a screening process in the search for toxicants to increase the effectiveness of oils for controlling scale insects. Where large increases in effectiveness were sought, small numbers of insects could be used for tests.

An attempt was also made to measure the effectiveness of different oils without toxicants. Table 5 summarizes the results, which generally followed the expected trend of increasing toxicity with increase in viscosity and increase in dosage. The higher toxicity of the emulsive light-medium oil over the straight light-medium oil was noted. Some contrary results obtained, however, indicated that the method was not sensitive enough to permit the use of so few test insects.

Mechanical improvements to control the filling of the micropipette are readily made possible, so that this most tedious procedure may be greatly improved. Presumably, one could greatly increase the sensitivity of the method by using a pure strain of scale insects of the same age reared under controlled laboratory conditions.

Summary.—To study the increase in toxicity of petroleum spray oils to the olive parlatoria scale due to the addition of toxicants to the oil, a method was developed for applying measured amounts of oil or oil-toxicant to individual scales.

A micropipette was used. Dosages were based on leaf area covered by the scale shell and were expressed in terms of 10^{-6} cc. per mm.^{2} of leaf area covered.

In 1943 the addition of 0.06 per cent rotenone (from derris resins containing 30 per cent rotenone) by means of a mutual solvent increased the toxicity of light, medium, and heavy oils, the increase

Table 5.—The toxicity of oils to adult female olive scale; dosage measured in 10^{-6} cc. per mm.^{2} of leaf surface covered by the scale.

Viscosity (Saybolt) and Unsulfonated Residue (UR) of the Oils Used	Dosage 2.00 Number Treated	2.00 Per Cent Dead	2.50 Number Treated	2.50 Per Cent Dead	2.75 Number Treated	2.75 Per Cent Dead
60 viscosity, 92 UR	19	10.6	10	20.0	—	—
70 viscosity, 92 UR emulsive[1]	20	35.0	10	80.0	—	—
70 viscosity, 92 UR	20	25.0	10	30.0	10	90.0
75 viscosity, 80 UR	20	25.0	10	20.0	10	70.0
77 viscosity, 60 UR	19	31.6	10	70.0	—	—
80 viscosity, 92 UR	20	10.0	10	60.0	—	—

[1] Emulsive agent, glyceryl dioleate.

being greatest for the light oil. The same trend of results was obtained when the oil or oil-rotenone treatments were made into emulsions and sprayed on scale-infested leaves in the laboratory.

In 1944, when the micropipette method

and light summer oil were employed, several chemicals, including nicotine alkaloid, showed little or no increase in toxicity at the concentrations used.

The addition of rotenone increased toxicity in all cases, the source of the rotenone being either ground cube root or derris resins.

An apparent synergism of petroleum extractives of cube root and *Velisciol Ar*-60 was noted.

Without refinement, the micropipette method does not appear sensitive enough to determine small differences in toxicity with only a few test insects.[1]—5-14-46.

[1] Acknowledgment.—The writer wishes to thank Dr. Roderick Craig of the University of California for help in making the micropipettes and for offering suggestions on their use.

LITERATURE CITED

Campbell, F. L., and R. S. Filmer. 1929. A quantitative method of estimating the relative toxicity of stomach poison insecticides. IV. Internatl. Cong. Ent., Ithaca, 1928, 2: 523–33.

McGovran, E. R. 1940. A measured drop method of applying liquid insecticides. U. S. Dept. Agr., Bur. Ent. Pl. Quar. ET-165.

Norton, L. B. 1940. Distribution of nicotine between water and petroleum oils. Ind. Eng. Chem. 32: 241–4.

Scholander, P. F. 1942. Microburet. Science 95: 177–8.

Smith, R. H. 1938. Microtechnique method of testing oil insecticides on scale insects. JOUR. ECON. ENT. 31: 632–3.

Observations on the Airplane for Application of Sprays and Dusts

D. O. WOLFENBARGER, *Florida Sub-Tropical Experiment Station, Homestead*

That airplanes may be used for distributing insecticides, fungicides, plant nutrients, herbicides, seed, or other materials to serve the needs of agriculture there is no doubt. There is no question, moreover, but that aircraft, specialized as they are for flying, have some limitations of use. Some questions that arise include, where, how, and when may they be used, and what may they be used for, to the benefit of mankind. Present uses of aircraft in the dispersion of insecticides, seeds and some other materials cover a wide range of projects. Crop dusting has been conducted for years for the control of cotton insects. Certain insecticide and seed distribution efforts, for example, have been so successful as to have passed the experimental stage. Other uses, no doubt, await development; some have been tried or suggested, such as the application of insect sprays for many crop plants, fungicides, plant nutritional materials, and herbicides. The extent of interest in the use of aircraft in the control of crop pests has increased greatly during and since World War II. A source of interest and one of the fundamental bases for the use of aircraft is the saving of labor.

Present intense interest in the use of aircraft for agricultural purposes appears to have exceeded thus far the ability of research efforts to provide sufficient guidance. This presentation, it is hoped, may add to our knowledge certain observations. Some data are presented on airplane spray deposits, and only general observations on some dusting operations. It is realized (1) that in the early stages of development or use of aircraft failures as well as successes may be recorded, and (2) that one piece of equipment or method cannot be expected to serve for every purpose or to solve every problem. A ground machine adapted to spray grove, orchard, or tree crops, for example, is not well adapted to spray pastureland crops.

A factor in the use of aircraft for distributing materials, and one necessitating serious consideration, is the control over the dust or spray materials being distributed. Drift of dust particles or spray droplets to adjacent areas constitutes a responsibility of the operator. This is chargeable to those applying the treatments, making them liable for damages whether the equipment used is aircraft. fog machine, speed sprayer, power duster, pump, traction, or hand applicator. Increasing lack of control over the final stopping place of spray and dust materials is associated with rapidity and lack of

human efforts to perform the coverage. Lack of particle or droplet control and rapidity of coverage are both augmented by the most modern equipment. The evolutionary trends of insecticide application means has ever been toward more widespread and uncontrolled distribution, greater volume, and, except within recent years, toward higher pressures. Lack of control means loss of material dispersed. It means also that plants or structures other than the objects to be treated, may be struck by spray droplets or dust particles.

Spray (or dust) materials may be placed on the top surfaces of leaves to control certain insects; with other insects they *must* be placed on the lower leaf surfaces in order to be effective. Applications of fungicides for plant disease control are effective in different ways also, depending on the fungus and the plants involved. It is important, therefore, to know the pest being attacked, the commodity being protected, and as many interrelated factors as is possible. Many or most ground spray or dust machines are adaptable for covering the lower and also the upper leaves. Can aircraft be so adaptable? It has been said that airplanes develop air currents, swirls, and eddies which make the air turbulent and provide more complete plant covering. It appears desirable, therefore, to study the dispersion patterns of deposits in order to provide more understanding of this factor and of other problems.

The distance from target to nozzle is another important factor from the standpoint of droplet or particle control, and to some extent on the amount of spray or dust deposit. A report of observations on dust deposits left by airplane for control of the white-fringed beetles may illustrate the principle involved. Plants in fields dusted by airplanes were observed to have more dust particles (per unit area) at periodic distances than at others. Most dust particles fell directly under the airplane as it dispersed the insecticide and fewest particles fell at the greatest distances from the dust nozzle. Studies of these plants indicated paths over which the plane had flown. It was thus possible to determine the width of swaths covered, distances not quite in agreement, however, with those reportedly covered. It is immediately obvious, from these and later observations, that dusting by airplane has not provided equal coverage.

A conclusion was inevitable from the observations that (1) if the deposit in the center of the swath was effective in controlling the pest the deposit in the margin was less effective, or (2) if the marginal deposits were effective in control a superfluous amount was deposited in the swath center. In so far as is known, there are no published data illustrating the amount or the effects of these inequalities. Recent and local observations of "precision" dusting illustrate the same inequality. They have shown also that the bottom surfaces of the leaves received from few to no deposits. This must be more especially true where dense growth or successively higher leaf coverings exist, as with corn several feet tall interplanted with velvet beans. This may be contrasted with targets having a single plane surface as a body of water, or a thin covering, as for example, most pasture lands.

Recent observations were made by the author of deposits by airplane spray equipment.[1] Deposits of potassium permanganate solution, which served as an indicator, falling on paper targets, showed that 100 feet was sufficient width to expect as the maximum range covered. Glass slides, 1 by 3 inches, were used thereafter as targets, with finely ground lime, 1 pound in 25 gallons of water, as the indicator. The slides were placed in line at 10-foot intervals, over a 100-foot distance in the target area perpendicular to the line of flight. Four slides, supported in saw kerfs in an upright stake, were placed at each 10-foot interval and ranged from 3 to 14 inches above the ground. Records were taken, therefore, illustrating the number of droplets deposited on the slides, (1) at distances from center of plane flight, (2) inches above ground level, and (3) top or bottom surface of slide at each position. The height of flight was at about 8 to 10 feet. Droplets ranged in size from pin point to several square millimeters. The area examined was near 2.25 square inches on each slide.

[1] The spray tank was fitted between the wheels, underneath the fuselage of a Navy biplane. A rotary type pump driven by an auxiliary propeller, located below and behind the regular power propeller, forced the spray into the feed pipe. The feed pipe was connected with a distributor pipe beneath the lower wing. Nozzles or outlets were placed at periodic distances along the pipe beneath the wing to disperse the fluid. A rate of application was 3 gallons of water at a propeller speed of 1750 revolutions per minute (about 85 miles per hour).

WIDTH OF SWATH.—Effects of distance from the plane path center are illustrated in table 1. It is observed that at distances beyond 20 feet, swath width of 40 feet, the number of droplets were fewer and decreased with distance increases to 50 feet. Factors which may alter the swath width include height of flight and wind velocity. More droplets were observed on the slide top surfaces in each average figure than on the slide bottom. The slide tops were in no instance wetted, only spotted. Coverage of the lower slide surfaces was very slight, even on the slide with the most droplet deposits.

Table 1.—Average number of droplets per slide surface at distances from center of plane path.

Date of Flight	Slide Surface	Distance in Feet					
		0	10	20	30	40	50
January 1	Top	58[1]	55	41	13	28	12
	Bottom	2	7	5	2	4	1
January 9	Top	70	72	68	36	38	8
	Bottom	3	2	1	1	1	0

[1] Rounded to nearest whole number.

HEIGHT ABOVE GROUND LEVEL.—Distances of 3, 7, 10 and 14 inches are listed as distances above ground for placement of the slides, although some slides varied as much as two inches more or less than listed. The summarized results are presented in table 2.

These data show that there were practically as many droplet deposits on the low as on the high slides over the range of 3 to 14 inches. The top slide surfaces had far more deposits than the bottom surfaces in table 1, as in table 2 above. In table 2, however, the higher placed slides appear to have received slightly more deposits on the bottom surfaces than the slides placed lower.

A study of the individual slides from which the above data are summarized shows that certain slides had comparatively more droplet deposits on the lower than on the upper surface. These same slides apparently had fewer deposits on the top surface than other slides in their position classification. This suggests that the air currents bearing the spray droplets struck one or the other of the slide surfaces. Possibly both, top and bottom, surfaces may not be expected to receive deposits from the type or mode of spray distribution equipment under observation.

Table 2.—Average number of droplets per slide surface, based on height of slide.

Flight Date	Slide Surface	Height of Slide Above Ground in Inches			
		3	7	10	14
January 1	Top	33	33	26	32
	Bottom	1	1	3	10
January 9	Top	45	44	47	38
	Bottom	1	1	2	1

A brief comparison of the droplet numbers on the surfaces may be of interest. A summarization is presented in table 3.

More droplets were observed on one day than another, and proportionately more deposits were observed on the bottom slide surfaces on this day. These differences seem more likely to exist as variations, however, rather than as possessing any particular significance.

CONCLUSION.—Swath width is seen as an important factor in the use of the airplane for spraying or dusting. More spray droplets and dust particles fell under the plane, and the droplet or particle numbers became less toward the margin of the swath covered. In comparing bottom and top slide surfaces the top surfaces received, on an average, over 90 per cent of the spray droplets leaving very sparse coverings on the lower surfaces. Although aircraft have their place in distributing spray and dust materials, more research is necessary before definite conclusions may be drawn.—5-1-46.

Table 3.—Total droplet deposits on top and bottom slide surfaces.

Flight Date	Total Droplets on Slides		Percentage	
	Top	Bottom	Top	Bottom
January 1	1256	153	89.1	10.9
January 9	1040	26	97.6	2.4
Combined dates	2296	176	92.8	7.2

Aerosols and Their Application

LYLE D. GOODHUE, *Aerosol, Inc., Neodesha, Kansas*

During the past few years insecticides in aerosol form (Goodhue 1942) have become a very important means of controlling insects. Extensive use by the armed forces has popularized this method of insecticide application in a far shorter time than would have been possible under ordinary circumstances. More than 40 million 1-pound bombs were made for the armed forces and about 30 million of these were used overseas. Although much waste occurred, as is usually the case in wartime, great benefit was obtained from the aerosol and there was almost universal praise for the relief it gave from annoying and disease-carrying insects.

General acceptance by service men is reflected in the civilian market. The aerosol bomb appears to have found a definite place in the households of the nation. Since V-J Day all but one of the original manufacturers of aerosol bombs have continued production. The manufacturers have made and sold more than 7 million bombs for civilian distribution. At the present time demand far exceeds the supply. The bombs have been improved mechanically and the formulas have been adapted for household use.

In common use the term "aerosol" has come to mean a solution of insecticides in a liquefied gas, generally sold in a 1-pound dispenser or "bomb." Technically an aerosol is a fine dispersion of a liquid or solid in a gas, so fine that the individual particles will remain suspended in air for periods varying up to 2 or 3 hours. This prolonged suspension provides a greater opportunity for the minute particles of insecticide to contact insects than larger particles, such as those in an ordinary fly spray (Fales & Goodhue 1944), which rapidly fall to the floor. Likewise, its ability to remain airborne makes it possible to drift an aerosol cloud for long distances under the proper meteorological conditions.

The particles in an aerosol range from 0.5 micron to 50 microns in diameter (Goodhue & Riley 1946). Above this range, the advantage of being airborne is lost. Particles smaller than 0.5 micron are of little insecticidal value because a lethal dose is collected far too slowly by the insect. For example, to achieve comparable results, an aerosol with insecticide particles 1 micron in diameter requires an exposure 85 times greater than one with particles 10 microns in diameter. The most effective range for confined spaces is between 10 and 20 microns diameter. Increasing the velocity of a small particle increases its effectiveness because more kinetic energy helps the particle pass through the streamline layer of air around the insect. Small, slow-moving particles are not easily deposited. For outdoor use the particle diameter of a drifting aerosol should be near 10 microns in order to allow as much coverage as possible. The velocity imparted by the wind gives sufficient precipitation on the insect.

There are methods of producing aerosols other than generation by liquefied gas but none has achieved economic importance. These methods include (a) incomplete combustion of materials containing insecticides, (b) spraying an oil solution of insecticides on a hot surface (Sullivan *et al.* 1940) to form a vapor which immediately condenses into a fog when cooled by contact with air, (c) thermal generation by heating a mixture of water and an oil solution of the insecticide until the water is converted into superheated steam, which, released through a nozzle, breaks up the insecticide solution into aerosol-sized droplets (Latta 1945), and (d) mechanical means, such as air-atomizing nozzles, revolving discs, etc.

LIQUEFIED GAS AEROSOLS.—Up to the present time the liquefied gas method (Goodhue 1942) has been the predominantly successful commercial means of producing insecticidal aerosols (Goodhue 1944). The solutions used to prepare them are composed of insecticides such as pyrethrum extract, DDT, thiocyanates, etc., and a non-volatile solvent such as cyclohexanone, aromatic solvents or sesame oil in a liquefied gas such as *Freon-12* (dichlorodifluoromethane). Such a solution is contained in a metal cylinder which is provided with a valve and nozzle. Upon opening the valve the vapor pressure of the liquefied gas ejects the fluid into the air where it boils violently and disperses

the insecticide in the form of an aerosol.

Hand dispensers vary in size. The widely used military and civilian model contains one pound of aerosol. Other dispensers hold from 0.33 ounce to 5 pounds. Industrial dispenser systems which are supplied from 145-lb. cylinders of aerosol have also been developed, as well as agricultural equipment with multiple outlets fed by one large cylinder.

Liquefied gas aerosols are best adapted to controlling insects in confined or restricted spaces. The military forces used a pyrethrum-sesame oil aerosol, and later a pyrethrum-DDT aerosol to destroy disease-carrying mosquitoes in airplanes (Goodhue 1943). The same aerosols was used to control insects in foxholes, tents, barracks, rooms, mess halls, etc. The treatment of a 27,000,000 cubic foot war plant for mosquitoes, using aerosols dispensed from a portable apparatus, increased worker efficiency enormously.

Liquefied gas aerosols will control a variety of household insects such as mosquitoes, flies, sand flies, fleas, adult moths, roaches, bed bugs, silver fish, crickets, ants and many others. An aerosol can kill only the insects which it contacts. If, however, a sufficiently high dosage is used the residue is effective against insects attempting to invade the place at a later time. This is easily demonstrated in the control of ants and fleas.

Aerosols have been widely used by international air lines since 1941 to destroy disease-carrying insects in the cabins of planes. They have also been used during and since the war to prevent the spread of agricultural insects such as the Japanese beetle.[1]

Factual experience does not support the principal objection of critics that aerosol insecticides are uneconomical. Considering the proportionately high insecticidal content, coupled with inherent efficiency of application, aerosol insecticides are competitive in price with insecticides in other forms. Furthermore, the convenience and cleanliness of an aerosol insecticide enhances its value to the consumer. Extensive observation indicates that an aerosol insecticide is more likely to be correctly applied than is an insecticide in any other form.

[1] Unpublished work by Randall Latta, L. D. Goodhue and associates.

A great deal of effort is being exerted by manufacturers to reduce the cost of the aerosol bomb. One approach to this end is the use of a low pressure propellent which can be used in a light metal container. This will reduce the price of the container but the cost of the contents is not easy to reduce without lowering quality. A regulation by the Interstate Commerce Commission states that in order to use a so-called "tin can" of more than 4 fluid ounces capacity, the pressure must not exceed 25 pounds per square inch at 70° F. Sufficient biological tests on an aerosol produced by this low pressure have not been made to determine its practical value. Higher pressures are permissible in containers with a capacity of less than 4 fluid ounces, making effective aerosols in cheap containers a distinct possibility. Without a doubt large numbers of "tin can" aerosol dispensers will be on the market next year. Only a shortage of tin and terne plate prevents their production now. Attempts to reduce the formula costs will result in the use of less or cheaper insecticides. Unless some control is exercised, the "tin can" aerosol business may degenerate to a point comparable to that existing with fly sprays before the war.

Another approach to a cheaper aerosol bomb is to employ a compressed gas as the propellent. It may be possible to use carbon dioxide at about 250 pounds pressure in the more expensive containers. Here a saving in the contents instead of the container would reduce the total cost. Such aerosols are inflammable and are therefore not acceptable at this time. Nevertheless, one company is attempting to market a soda siphon cartridge using a solution of carbon dioxide in acetone as the propellent.

GREENHOUSE AEROSOLS. — Aerosols have been used to control a variety of insects in greenhouses. Nicotine in an aerosol is twice as effective as in a smoke from a burning mixture (Smith & Goodhue 1943). Lorol thiocyanate aerosols controlled cyclamen mite on snapdragons (Goodhue & Smith 1944). DDT aerosols were effective on thrips, white flies, aphids, sow bugs, ants and crickets (Smith & Goodhue 1945). Pyrethrum aerosols gave good control of mushroom flies in mushroom houses (Goodhue 1942). Most of the applications have been made from

1-lb. bombs but recently a light container[1] holding 10 lbs. of solution was used. It was equipped with a flexible hose attached to a 2-foot pipe with a nozzle on the end. This was used like a knapsack sprayer. Aerosols would appear to have a definite use in greenhouses since these are enclosures where the full benefit of the insecticide will be obtained. Also the crop is of sufficient value to justify the use of a higher quality product.

A good formula which gave a maximum effectiveness with little or no plant injury consists of the following:

DDT (Technical	5%
Velsicol AR-60	10
Freon-12	85

AGRICULTURAL AEROSOLS.—Floyd F. Smith, L. P. Ditman and the writer have published several papers on the application of aerosols for the control of certain field crop insects (Smith *et al.* 1945), principally the pea aphid. At first, hand drawn machines were constructed, consisting of a covered framework under which several nozzles were mounted. A tank of aerosol solution was mounted on the top and the solution conducted through a filter by small copper tubing to the nozzles. Smaller row crop machines with only three nozzles were also made and used on truck crops. When a DDT aerosol was applied insects susceptible to this insecticide were killed. Such insects as onion thrips, lace bugs on eggplant, the Colorado potato beetle, the aster leafhopper and certain aphids were easily controlled.

For experiments during the next season larger machines were constructed. One, which covered a swath 24 feet wide, was built on the back of a jeep. A tank containing 80 lbs. of aerosol solution—enough to cover from 8 to 10 acres—was carried on the jeep. At a speed of 5 miles per hour control of the pea aphid was generally over 95 per cent (Ditman 1945). Another large machine was built to treat potato insects in Maine. It was attached to the back of a row-crop tractor. Potato insects were easily killed but no known fungicide capable of controlling the blight can be applied by this method (Bronson & Smith 1946).

The formula most generally used on truck and field crops was as follows:

DDT (Technical Grade)	5%
Cyclohexanone	5
Velsicol AR-60	5
Acetone	35
Methyl chloride	50

This formula caused little or no plant injury when applied at dosages up to 20 pounds per acre. When a machine is stopped without turning off the flow of aerosol, plant injury in the area will occur. The cost of materials in the formula is less than 20 cents per pound and can be applied economically to many crops if the solution is prepared by the grower.

This method of application has been tested most extensively in Maryland on the pea aphid, against which it has a good chance to succeed (Ditman *et al.* 1946). However, there are some problems yet to be solved before the method will be entirely practical. It will be necessary to provide growers with aerosol solutions in tanks of convenient size and design at a cost competitive with other methods. Industrial engineering is needed to develop trouble-free, light, and inexpensive equipment with enough advantages to make the method attractive.

THE FOG GENERATOR.—Thermal-generated aerosols are formed by heating a mixture of water and oil-insecticide solution (Latta 1945). A 50–50 mixture of water and the oil solution, pumped through a coil suspended in a furnace, is heated sufficiently to convert the water to superheated steam. Pressure generated by the steam forces the mixture through a nozzle, breaking it into small particles. The range of particle size can be regulated by varying the viscosity of the oil, or the temperature to which it is heated. A relatively non-volatile oil solvent for the DDT should be used or the aerosol particles will shrink too rapidly by evaporation during application.

Thermal-generated aerosols[2] are strictly for large scale use. They are applied to outdoor areas by drifting the cloud across the desired area. Usually the generator is mounted in a truck and moved back and forth across a front at right angles to the direction of air movement. The cloud

[1] Unpublished work by Floyd F. Smith and Lyle D. Goodhue.

[2] Randall Latta of the Bureau of Entomology and Plant Quarantine has led the investigation of thermal-aerosols and their applications.

must be applied under meteorological conditions which will hold it close to the ground. Inversion conditions (a layer of colder air next to the ground) are the most favorable and usually occur during the periods near dawn and dusk. A wind movement of from 1 to 4 miles per hour is desirable.

The concentration of these aerosols, and therefore their effectiveness, is greatest nearest the generator and diminishes with distance. To obtain a high degree of control at a given distance it is necessary to overdose the intervening area. For this reason it is more economical to treat in narrow strips than in deep areas. Mosquito adults and larvae were controlled downwind from the point of generation for distances ranging from 1200 feet in heavily wooded areas to nearly a mile in open terrain. Gypsy moth larvae in naturally infested forests were apparently completely wiped out in strips up to 900 feet wide. Furthermore, enough residue remained to be repellent to migrating larvae, which prevented reinfestation in all except the marginal areas.

Thermal-generated aerosols were found to be very toxic to adult horn flies on cattle. Herds can be quickly treated and enough residue remains to prevent reinfestation for several days. Also filling a stable with this aerosol will leave enough residue to reduce the fly population satisfactorily for several weeks.

SUMMARY.—The use of the liquefied gas aerosol by the armed forces has given an impetus to a new branch of the insecticide industry which has continued in business to supply a demand in the civilian market. The aerosol is being used under widely varying conditions to control household insects, disease-carrying insects and, experimentally, insects that destroy field crops. It is a good method of applying greenhouse insecticides. The thermal-generated aerosols show promise for the control of insects over large outdoor areas and in large enclosures where liquefied gas aerosols are not economical.

LITERATURE CITED

Bronson, T. F. and Floyd F. Smith. 1946. Control of aphids on potatoes in northeastern Maine. JOUR. ECON. ENT. 39(2): 189–94.

Ditman, L. P. 1945. War on pea aphids enters new phase in Maryland experiments with DDT aerosol. The Canner 101(12): 35.

Ditman, L. P. and L. D. Goodhue, Floyd F. Smith, and George Burkhardt. 1946. Insecticidal aerosols for pea aphid control—Second Report. JOUR. ECON. ENT. 39(2): 199–204.

Fales, J. H. and L. D. Goodhue. 1944. Aerosols vs. oil spray insecticides. A study of comparative efficiency. Soap and Sanit. Chem. 20(7): 107–8.

Goodhue, L. D. 1942. Insecticidal aerosol production. Spraying solutions in liquefied gases. Indus. & Engin. Chem. 34(12): 1456–9.

Goodhue, L. D. 1943. New mosquito-control method, developed for Army, described. New York Herald Tribune, Nov. 21, 1943, Sect. VIII, p. 15. (Reprinted in book "1943 New York Herald Tribune Forum" under title "War Against Mosquitoes," pp. 162–6, 1944.)

Goodhue, L. D. and F. F. Smith. 1944. The effect of some insecticides in aerosol form against the cyclamen mite on snapdragon. JOUR. ECON. ENT. 37(2): 214–8.

Goodhue, L. D. 1944. Military needs stimulate development of insecticidal aerosols. Chem. Indus. 54(5): 673–5. Also published under title "Insecticidal Aerosols" in JOUR. ECON. ENT. 37(3): 338–41.

Goodhue, L. D. and R. L. Riley. 1946. The particle-size distribution in liquefied gas aerosols. JOUR. ECON. ENT. 39(2): 223–6.

Latta, R. 1945. Preliminary investigations on heat-generated aerosols for the control of agricultural pests. JOUR. ECON. ENT. 38(6): 668–70.

Roark, R. C. 1942. Definition of aerosol. JOUR. ECON. ENT. 35(1): 105–6.

Smith, F. F. and L. D. Goodhue, 1943. Toxicity of nicotine aerosols to the green peach aphid, under greenhouse conditions, JOUR. ECON. ENT. 36(6): 911–4.

Smith, F. F., L. P. Ditman and L. D. Goodhue. 1945. Experiments with aerosols against some pests of truck crops. JOUR. ECON. ENT. 38(2): 189–96.

Smith, F. F. and L. D. Goodhue. 1945. Aerosols to control onion thrips and other pests in greenhouses. JOUR. ECON. ENT. 38(2): 173–9.

Sullivan, W. N., L. D. Goodhue, and John H. Fales. 1940. Insecticide dispersion. A new method of dispersing pyrethrum and rotenone in air. Soap and Sanit. Chem. 16(6): 121, 123, 125.

Resistance of Soybean Varieties to Japanese Beetle Attack[1]

BECKFORD F. COON, *Pennsylvania State College, State College*

Twenty-six varieties of soybeans were planted in 1944 to test varietal resistance to Japanese beetle attack. The plots, situated at Lancaster and Manheim, Pennsylvania in Lancaster County, were planted by hand in 42-inch rows each two rods long and with five replications. Paths four feet wide separated the replicates.

PROCEDURE AND RESULTS.—Height readings were taken on July 3 and 17 and September 11 at Lancaster, and on June 23, July 17 and August 28 at Manheim. Plant height on the last dates of count represent mature heights, and are shown in table 1. Average height ranged from 24 to 57 inches, with a mean of 39.7

Table 1.—Field data covering various factors used to measure Japanese beetle response in soybean varieties at both Lancaster (Lanc.) and Manheim (Manh.). 1944.

Variety	Plant Height 9/11 Lancaster	Plant Height 8/28 Manheim	Japanese Beetle Code 7/13 Lancaster	Japanese Beetle Code 7/29 Lancaster	Japanese Beetle Code 8/10 Lancaster	Japanese Beetle Code 7/28 Manheim	Recovery Lancaster	Recovery Manheim	Lodging 9/25 Lancaster	Lodging 9/21 Manheim
	inches									
Lincoln	38	43	1.7	4.1	3.0	3.1	1.0	1.9	2.5	1.5
Gibson	42	41	1.1	3.7	1.5	2.1	1.0	1.0	3.1	3.0
Chief	47	55	1.0	2.9	1.8	2.1	1.0	1.2	3.2	3.0
Scioto	41	47	1.2	4.2	3.0	3.5	1.0	1.5	4.2	4.0
Viking	50	53	1.0	2.9	1.5	2.1	1.0	1.4	3.7	3.5
Potoka	38	46	1.2	4.9	2.0	3.0	1.0	1.1	2.8	3.0
Ranger	31	36	1.0	3.4	1.3	2.2	2.0	1.7	1.7	1.0
Mingo	37	54	1.0	4.5	3.0	3.4	2.0	1.9	3.1	3.0
Illini	38	47	1.0	2.3	3.5	2.7	1.0	1.5	3.7	3.0
Dunfield	38	41	1.4	4.4	3.0	3.9	1.0	2.0	3.6	3.0
Mansoy	44	53	1.2	4.3	4.5	3.1	1.0	1.6	3.4	2.0
Late Pennsoy	38	54	1.2	3.7	2.0	2.9	1.0	1.5	3.1	2.0
Harbinsoy	52	56	1.0	4.2	5.0	2.9	2.0	1.0	4.4	4.0
Penn State 105-38	37	37	1.6	4.5	1.0	3.8	1.4	2.6	4.3	1.8
Kingwa	40	55	1.0	4.3	4.0	3.1	1.0	1.2	3.2	2.5
Pennsoy	37	44	1.2	4.5	2.0	3.7	1.0	2.7	2.8	2.0
Manchu	37	41	1.6	4.3	3.5	3.9	1.0	2.3	4.1	4.0
Type 117	36	44	1.2	3.5	4.0	2.5	1.0	1.2	2.9	1.5
87-42	36	31	1.6	4.9	3.0	4.2	2.0	2.6	2.5	2.0
90-42	48	47	1.1	4.6	3.5	3.7	1.6	2.0	4.0	3.5
Richland	28	35	1.5	5.0	5.0	4.7	3.0	4.0	1.2	1.0
Wilson 5	53	42	1.0	2.7	3.0	3.1	1.2	1.2	3.6	3.0
Wisconsin 3	37	48	1.6	4.5	4.0	3.9	2.0	2.4	3.9	3.0
Hobara	24	34	1.8	4.8	3.0	3.5	3.0	3.4	1.2	1.0
Virginia	57	36	1.1	4.3	4.0	3.9	1.4	1.2	3.8	5.0
Earlyanna	28	—	1.0	5.0	3.0	—	3.0	—	2.4	—
Average	39.7	44.8	1.2	4.1	3.0	3.2	1.5	1.8	3.2	2.7

Varieties were planted at random in single rows with 400 seed evenly spaced in each two-rod row length. Planting occurred on May 16 and 17 at Manheim and on June 2 and 3 at Lancaster. One-half of each row was harvested for hay and the remaining half for grain yield.

[1] Authorized for publication on March 13, 1946, as paper No. 1318 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

inches at Lancaster, and from 31 to 56 inches with a mean of 44.8 inches at Manheim. Planting dates undoubtedly influenced this difference of 5.1 inches increase in height at Manheim with its 16 days earlier growth.

Japanese beetles began invading the plots in early July at Lancaster and somewhat later at Manheim. A count was completed on July 13 at Lancaster, but insuf-

ficient beetle feeding had occurred in Manheim on July 17 to make a count of any significance. Beetle injury to foliage was made by establishing a coded rating for all counts. Those varieties which had none or very little beetle leaf feeding were placed in code 1 and those with the most severe injury in code 5. Codes 2, 3 and 4 were intermediate values of these two extremes. Each replicate was coded separately and the five averaged.

From table 1 it is seen that the average coded value of a count taken on July 13 at Lancaster was 1.2 indicating very little Japanese beetle feeding in any plot or variety. On July 29 the ratings had risen to the high average value of 4.1 indicating severe plant injury. The average for varieties was from 2.3 to 5.0. This indicated the period of greatest beetle activity, subsequent plant injury and the critical period of the season. The last count was made on August 10 with a mean code rating of 3.0. This indicated that the peak of beetle activity had passed and that the plants had begun their period of recovery.

Injury ratings for the July 29 count showed that none of the varieties were distasteful to the beetles for all were fed upon. Observations tended to indicate furthermore that location may have influenced beetle injury, because varieties in one section of the field may have been heavily damaged while the same ones in another section may have escaped to a large degree.

By reference to the July 29 count in table 1, the relative resistance of varieties to Japanese beetle feeding can be observed. All varieties were susceptible and only four (Chief, Viking, Illini and Wilson 5) could be considered moderately resistant.

The inherent character of growth seems to be an important factor following the peak of beetle activity. This factor is spoken of as "recovery" and is associated with plant maturity. Early varieties make their maximum growth up to and including the period of beetle activity. Their maturity is reached at the time the Japanese beetles are disappearing. Later varieties, although making growth all during the period as above, will continue to grow after the beetles have reached their peak and have disappeared. This means that new leaves and branches appear and cover up the early plant injury to such an extent that it is not apparent on the mature plant. This also means that foliage increase will result in increased hay yield and will furnish food for grain production.

Table 1 shows the coded ratings on plant recovery as taken for both plots. In Lancaster the ratings were taken from 1 to 3 with code 1 representing good recovery and code 3 poor recovery. In Manheim the codes were from 1 to 5, with code 1 representing good recovery and code 5 poor recovery. The mean code value at Lancaster was 1.5 and 1.8 at Manheim. It can be seen from the table that early varieties such as Earlyanna and Hobara resulted in poor recovery.

Heavy rains occurred during the growing season and lodging in a number of varieties was noticed. Lodging was coded from 1 to 5 with code 1 representing little or no lodging and code 5 heavy lodging. Table 1 presents the results for both plots. A correlation was found between lodging and maturity. This association probably results from plant height as well as maturity, for the late varieties are also the tallest.

The plots were harvested for hay on September 7 at Manheim. The Lancaster hay yield was lost during curing. In Manheim the plants were cut off at ground level with hand scythes or hedge clippers and spread out in the row to dry. The plants were then all tied together and weighed with a pair of milk scales suspended from a tripod. Weights were recorded in pounds and tenths for each plot and computed into tons per acre.

Table 2 presents the hay yield of the Manheim plot in tons per acre. Yields ranged from 1.94 to 4.46 tons. Several scattergrams were prepared between various factors and hay yield. A good correlation was found between Japanese beetle injury and yield, figure 1. This is partly influenced by seasonal maturity and recovery after the peak of beetle feeding but shows that the greater the Japanese beetle feeding the greater the decrease in hay yield. The correlation between hay yield and recovery from beetle injury is also shown in figure 1 wherein the greater the recovery, the greater the yield. Recovery was greatest in later maturing varieties which also gave greatest yield, and which were taller than early maturing varieties.

The correlation between height and

yield was not as good as the ones above although in general the shortest varieties tended to have the smallest yields. This decrease in correlation was probably influenced by recovery to a large degree. Figure 1 shows the trend wherein yield increased as height increased from 1 to 4 on the abscissa.

The rod row remaining after hay harvest was cut for grain yield on October 11 to 12 in Lancaster and October 24 at Manheim. The plants were cut off at ground level, bundled and later threshed for grain weights, shown in table 2 as bushels per acre. The Lancaster yields ranged from 25.5 to 45.2 bushels per acre with an average of 35.9 bushels. At Manheim the range was 24.1 to 44.1 bushels with an average of 34.4 bushels. The average yield per variety for both plantings ranged from 25.8 to 44.0 bushels per acre with a mean value of 35.45. On the average the Lancaster plots produced 1.51 bushels per acre more than the Manheim plots which were planted two weeks earlier and had an average height of 5.1 inches more than at Lancaster.

Table 2.—Yields of all varieties in bushels of grain per acre and tons of hay per acre, 1944.

Variety	Hay	Grain		
	Manheim	Lancaster	Manheim	Average
	Ton/Acre	Bushels per acre		
Lincoln	3.63	38.9	40.9	39.9
Gibson	4.01	42.6	44.1	43.4
Chief	3.46	42.6	38.7	40.7
Scioto	3.08	37.6	30.8	34.2
Viking	4.00	40.5	40.2	40.3
Potoka	4.46	45.2	42.7	44.0
Ranger	2.91	33.5	32.7	33.1
Mingo	3.12	36.9	36.8	36.9
Illini	3.61	31.2	38.8	35.0
Dunfield	3.08	38.2	28.8	33.5
Mansoy	3.53	36.6	34.6	35.6
Late Pennsoy	3.62	38.2	37.5	37.9
Harbinsoy	3.16	31.0	30.9	31.0
Penn State 105-38	3.02	36.9	33.4	35.2
Kingwa	3.92	32.3	35.1	33.7
Pennsoy	3.25	36.0	31.7	33.9
Manchu	2.85	32.1	32.3	32.2
Type 117	4.01	36.7	32.4	34.6
87-42	2.94	31.8	35.8	33.8
90-42	2.86	34.7	34.2	34.5
Richland	2.32	25.5	26.0	25.8
Wilson 5	3.16	30.1	28.4	29.3
Wisconsin 3	2.97	34.6	33.7	34.2
Hobara	1.94	30.7	24.1	27.4
Virginia	3.38	36.1	36.1	36.1
Earlyanna	—	29.4	—	29.4

A graph, figure 1, between plant height and grain yield indicated that shortest varieties gave lowest yield. The curve rose as height increased up to a certain point and then leveled off, or turned downward. This indicates that in varieties giving the greatest height that grain production may have suffered. The greater average height of the Manheim plot and the lower average yield lends emphasis to this supposition.

The correlation between grain yield and recovery from beetle injury, figure 1, indicated that with greatest recovery resulted greatest yield. This trend is probably associated with plant height because height and recovery are related. The correlation was not as good as in the case of hay yield and recovery.

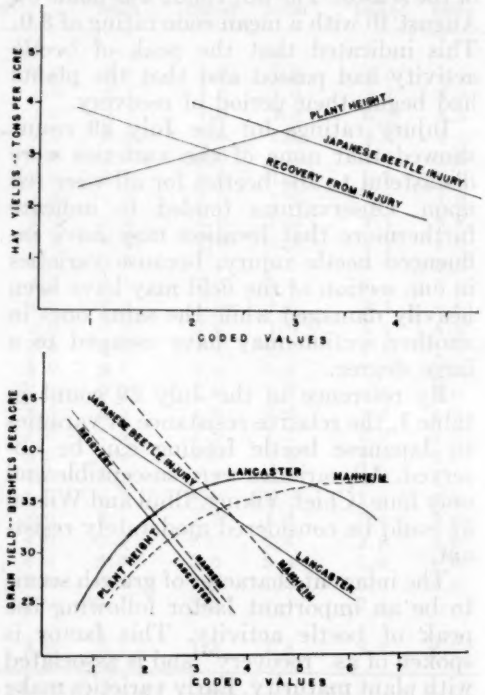


FIG. 1 (Above).—Correlation between hay yield and various factors influencing Japanese beetle injury. See text for code values. (Below).—Correlation between grain yield and various factors influencing Japanese beetle injury. See text for code values.

The correlation between maturity and grain yield indicated that later maturing varieties gave greatest yield. This is also related to the functions of recovery and plant height.

The correlation, figure 1, between Japanese beetle injury and grain yield showed that greatest yield occurred with the smallest beetle injury.

SUMMARY.—All 26 varieties of soybeans were found susceptible to Japanese beetle attack. Greatest injury had occurred by the last of July in all plots.

Late varieties recovered from the beetle injury by continued growth after the beetles disappeared. Early varieties failed to make this recovery.

Plant maturity and mature plant height are related and hay yield was found to increase with increased plant height and late maturity.

Increased recovery from beetle injury resulted in increased grain yield. Increased beetle injury resulted in decreased grain yield.

Grain yield increased with increased mature plant height up to a certain point beyond which yield decreased. It is possible that excessive plant height was made at the expense of grain production.—4-20-46.

Effect of Temperature and Relative Humidity on Sugar Concentration of Nectar

E. OERTEL, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, Baton Rouge, Louisiana*[1]

It has been recognized for some time that temperature and relative humidity play a prominent role among the factors that influence the sugar concentration of nectar. Recent American investigators are agreed that sugar concentration increases as relative humidity decreases, and vice versa. Thus, Park (1929) has reported, "Sugar concentration in nectar was found to vary inversely with relative humidity." Experimental work and observations by Vansell (1940, 1941) indicate that changes in the relative humidity, among other factors, influence changes in the per cent of sugar in the nectar from certain flowers. Scullen (1940) has shown that there is a highly significant negative linear correlation between relative humidity and the sugar concentration in fireweed nectar. He also obtained temperature records during his investigations, but the effect of temperature upon sugar concentration is not shown.

To ascertain the cause of the variation in the sugar concentration of some southern nectars previously reported (Oertel 1944), a study has been made at Baton Rouge, La., of the temperature and the relative humidity prevailing during the collection of those nectars.

METHOD.—To determine the sugar concentration of the nectar of a number of common southern honey plants Oertel (1944) caught honeybees on the blossoms and determined the concentration of the contents of the honey stomach by means of an Abbé refractometer. In some cases the nectar from one bee's stomach was ample for a clear reading, but when the stomachs were only partly filled the contents of two or more were used. Linear regressions and linear correlations were calculated between temperature, relative humidity, and sugar content of nectar of the goldenrod *Solidago altissima* and white clover, *Trifolium repens*. The temperature and humidity data were obtained from recording instruments located in a U. S. Weather Bureau shelter. Bees were captured close to the shelter in some instances and as far as 4 miles away in others. It is possible that the relative humidity of the air surrounding the blossoms was not the same as that in the shelter.

OBSERVATIONS.—The mean sugar concentration for goldenrod and white clover nectar differs from year to year, as shown in table 1. Much more variability is apparent for the white clover nectar than for the goldenrod nectar. The difference may be due to seasonal influences, since the white clover observations were obtained over a 2-month period, April and May, while those for goldenrod were made over a period of 12 to 15 days in October.

EFFECT OF TEMPERATURE.—There is a highly significant relationship between temperature and sugar concentration for

[1] In cooperation with Louisiana State University.

Table 1.—Relation of sugar content of goldenrod and white clover nectar to temperature and relative humidity.

Year	Observations[1]	Sugar: Mean	Sugar: Standard error of the mean	Mean Temperature	Mean Relative Humidity
	Number	*Per Cent*		°F.	*Per Cent*
			Goldenrod		
1941	30	28.6	1.0	84.8	61.2
1942	15	40.1	0.76	80.4	45.8
1943	11	29.5	1.0	76.9	47.7
			White Clover		
1938	15	36.0	2.9	77.5	48.8
1941	26	43.3	2.05	77.0	58.0
1943	17	44.6	2.64	79.2	51.5

[1] Each observation is composed of 1 to 6 individual refractometer readings. For example, for white clover in 1943, 52 readings comprise the 17 observations.

white clover in 1943, and a significant relationship in 1938, as shown by the correlation coefficients in table 2 and the regression line in figure 1. The correlation coefficients are nearly significant for white clover in 1941 and for goldenrod in 1941 and 1943. Note that the 1943 value for goldenrod is negative. No reasons are known for the variations from year to year.

EFFECT OF RELATIVE HUMIDITY.—The effect of relative humidity upon the sugar concentration of goldenrod and white clover nectar is shown by the correlation coefficients in table 2 and the regression line in figure 2. There is a highly significant negative correlation between relative humidity and the sugar concentration of nectar for white clover in 1938 and 1943, and a significant negative correlation for goldenrod nectar in 1941. No reasons are known for the variations in results from year to year, but the following information may be of interest.

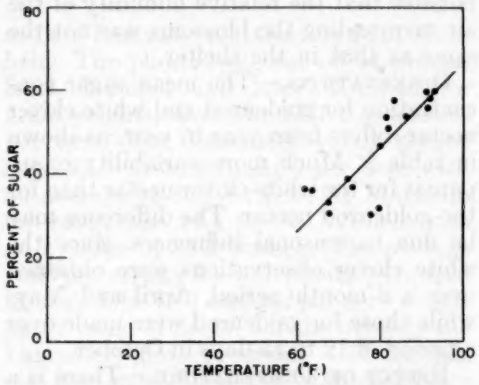


FIG. 1.—Regression of per cent sugar in nectar on degrees of temperature for white clover in 1943.

Table 2.—Coefficients of correlation (r) between temperature and relative humidity and the sugar concentration of nectar.

Year	Temperature	Relative Humidity
	Goldenrod	
1941	+0.356‡	−0.435*
1942	+0.001	+0.291
1943	−0.519‡	−0.273
	White clover	
1938	+0.536*	−0.811†
1941	+0.355‡	−0.137
1943	+0.821†	−0.850†

* Significant.
† Highly significant.
‡ Not quite significant.

Two samples of clover nectar, taken at 2:30 and 3:30 p.m. on May 21, 1941, have an important effect on the size of the correlation coefficient and the direction of the regression line for that year. If these samples are omitted from the calculations, the correlation coefficient becomes −0.436 a significant value, instead of −0.137, which is not significant. The average sugar concentration and relative humidity at 2:30p.m. were 48 and 88 per cent, respectively, and at 3:30 p.m. 59 and 96 per cent. The relative humidity rose between noon and 4 p.m. from 52 to 100 per cent, and the temperature dropped from 86° at 2 p.m. to 74° at 4 p.m. Possibly a lag in the effect of the moisture in the air upon the nectar in the blossoms, or the fact that the humidity in the field was not so high as that surrounding the hygrothermograph, may have been responsible for these extreme deviations.

The contradictory and somewhat confusing effects of temperature and relative humidity upon nectar concentration at

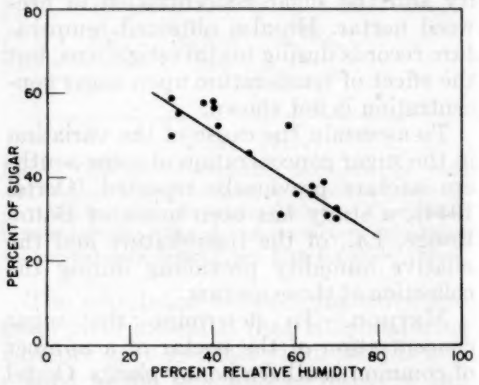


FIG. 2.—Regression of per cent sugar in nectar on per cent relative humidity for white clover in 1943.

Baton Rouge may indicate either that not enough samples were used, or that unknown, unmeasured influences at times obscured or delayed the effects of the relative humidity and temperature. For example, Vansell (1941) collected nectar from alfalfa blossoms the stems of which were kept in a saturated atmosphere. The sugar concentration of blossoms grown in dry soil was nearly twice as high as of those grown in wet soil. Soil temperature, soil nutrients, wind velocity and direction, plant species, blossom structure, nectar quantity, and other factors may partially or completely obscure the effects of temperature and relative humidity. Perhaps for such reasons rapid changes in the weather are not immediately reflected in the nectar concentration.

The probability that factors other than those mentioned are of importance in a study of the sugar concentration of nectar seems to be emphasized. Available nectar in the blossoms is constantly being exposed to a number of agents, also to the interaction of these agents. Hambleton (1925) shows that weather in the spring may have different effects upon the changes in weight of a colony of bees than weather in the fall. He also determined that about 10 per cent of the net gain in weight in the spring and nearly 30 per cent in the fall were due to unknown factors. In spite of such apparent barriers as shown above, some progress in the study of various elements influencing the size of the honey crop can be made by determing first the effect of each and then the effect of the various elements in combination.

Since it has been shown that the relative humidity and temperature may influence the sugar concentration of some southern nectars, a truly representative average concentration figure for that area can best be obtained by taking samples at different times of day and probably over several seasons. For instance, if samples are obtained only when the relative humidity is low, the average values of the sugar concentration are likely to be higher than if samples are taken when the relative humidity is high. Beekeepers are well aware that in some seasons, even though conditions seem favorable, less than normal honey crops are obtained. Factors other than temperature and relative humidity may have an important effect upon the nectar.

SUMMARY OF RESULTS.—In some seasons at Baton Rouge, La., there is a significant negative linear correlation between relative humidity and the sugar concentration of nectar from certain plants; and a significant positive linear correlation between temperature and sugar concentration. It is also apparent that at times other factors obscure the effects previously noted. Probably a number of unknown variables are associated with the variations in the sugar concentration of nectar. A representative sugar concentration value for a honey plant in a locality can best be obtained by taking nectar samples at different times of day and for several seasons.—5-7-46.

LITERATURE CITED

Hambleton, J. I. 1925. The effect of weather upon the change in weight of a colony of bees during the honey flow. U. S. Dept. Agr. Bul. 1339.

Oertel, E. 1944. Variation in the sugar concentration of some southern nectars. JOUR. ECON. ENT. 37: 525–7.

Park, O. W. 1929. The influence of humdiity upon sugar concentration in the nectar of various plants. JOUR. ECON. ENT. 22: 534–44.

Scullen, H. A. 1940. Relative humidity and nectar concentration in fireweed. JOUR. ECON. ENT. 33: 870–1.

Vansell, G. H. 1939. The sugar concentrations of western nectars. JOUR. ECON. ENT. 32: 666–8.

Vansell, G. H. 1940. Nectar secretion in poinsettia blossoms. JOUR. ECON. ENT. 33: 409–10.

Vansell, G. H. 1941. Alfalfa nectar and the honeybee. JOUR. ECON. ENT. 34: 21–3.

Influence of Characteristics of the Puncture in Potatoes on Parasitism of Potato Tuber Moth by *Macrocentrus ancylivorus*

CHAS H. MARTIN, *University of California, Albany*

The larvae of the potato tuber moth, *Gnorimoschema operculella* (Zell.) can enter very immature potatoes at any location, but as the potato matures the skin becomes sufficiently tough to restrict entry of the tuber moth near the eyes. Finney *et al.* (1944) found that larvae could enter the potato if the tough skin was punctured. This permitted large numbers of tuber moths to be reared in individual potatoes for the breeding of *Macrocentrus ancylivorus* Rohwer. The puncturing was done either by hand with a heavy leather mitten studded with tacks or by machinery (Smith 1945).

In a series of preliminary experiments the *Macrocentrus ancylivorus* populations bred from tuber moth infesting potatoes with round punctures, 1.5 mm. in diameter, were compared with populations bred from tuber moth infesting potatoes with slit-shaped punctures, 0.5 mm. wide and 1.3 mm. long. The data from 40 pairs of trays in six experiments made over a period of 3 months showed an average of 1.2 to 3 times as many *M. ancylivorus* from tuber moth infesting the potatoes with round punctures. For individual pairs of trays the difference ranged from 1.1 to 50-fold. In a number of cases there were no differences in moth populations between puncture types but there were always differences in the numbers of parasites.

These observations were extended to determine if the differences in the parasite populations were directly correlated with the characteristics of the puncture or if the relationship was indirect because the characteristics of the puncture affected moth populations.

TECHNIQUE.—As table 1 shows, taper, cylindrical, and slit-shape punctures were tested. Two depths and three diameters were used for the taper and cylindrical types. While the cylindrical holes in the potatoes were of the same diameters as the punches, in some cases the diameters of the taper holes were not uniform with the diameters of the punches. The diameters of the smallest taper holes were the same as for the punches, but the largest taper punch made holes smaller than its own diameter. At the 2 mm. depth the middle-size punch made holes smaller than its own diameter, but for the 5 mm. depth there was little difference.

Three slit holes of approximately the same sizes as the taper and cylindrical holes were made with 2 and 5 mm. depths. The sizes of the holes made by the flattened, diamond-shaped punches were usually either smaller or larger than the punch. The smallest punch was 0.25×1.25 mm. but the resulting slit for both depths was 0.2×1.0 mm. The middle size punch was 0.76×1.26 mm. but the hole for the 2 mm. depth was smaller, and for the 5 mm. depth was larger than the punch. The largest punch was 2.3×2.5 mm. but the holes for the 2 mm. depth were 1.76 ×3.0 mm., and for the 5 mm. depth they were 1.25×4.66 mm.

The differences between the punch dimensions and that of the holes in the potato seemed related to the resiliency of the potato flesh. This quality was in turn correlated with the age and variety of the potato. The potatoes used in these experiments were old Burbanks.

When the slit punch was inserted into the potato, there was a tendency for the flesh to split beyond the cutting edge of the punch along the long axis. When the punch was withdrawn, the ends of the slit closed slightly to completely, but the degree that the main hole remained open was in relation to punch size, the depth of the hole and the resiliency of the potato flesh.

For parasite studies five potatoes, each with 25 punctures spaced 6 to 7 mm. apart and grouped on one side of the potato, were used for each category. Sixteen potatoes were used for each category for moth studies. The potatoes were randomized in each tray.

Thirteen days after the initial infestation, each potato was transferred to an individual cage so as to obtain separate records. The larvae began emerging 14 days after the initial infestation. The records in tables 1 and 2 are for moth

pupae and for the cocoons of the parasite.

DIAMETER OF PUNCTURES (MOTHS).—There were disproportionate increases of moth populations in relation to the diameters of the punctures (Table 1). The grand totals for diameters show the greatest increase between the smallest and middle size diameters, while the least was between the latter and the largest diameter. The data for slit punctures indicate that shape and depth were sometimes more dominant than the diameter factor.

In other experiments there were no population differences between the two largest diameters. The data for shallow punctures in table 2 show that a few more moths were produced with the middle-size puncture.

DEPTH OF PUNCTURE (MOTHS).—The general totals for depth of puncture effects on tuber moth populations indicate that more moths were bred with the deepest puncture (Table 1). However, examination of the subdivisions of the data show that depth did not always exert an influence. The grand totals for shape and depth show that larger moth populations were bred with the deepest taper and slit punctures, but this difference did not show for the cylindrical punctures. The strongest influence of depth on moth populations for any one puncture category was for the largest slit puncture; probably much of this increase was due to the increased area of the inside of the puncture rather than to depth (See dimensions in text). Also, there was a wide difference in moth populations between depths for the smallest taper puncture. Table 2 shows similar trends.

SHAPE OF PUNCTURE (MOTHS).—The grand totals for shapes in table 1 indicate that they may affect the tuber moth populations to a degree. The differences are irregular from one shape category to another. Shape had little effect on moth populations for the smallest punctures. However, the moth populations of the middle-size taper and cylindrical puncture were 1.3 times greater than for the same size slit-puncture. Also, 1.2 more tuber moths were bred with the largest cylindrical puncture than with the slit puncture. These differences were highly significant. Hence, there is a general tendency for the larger taper and cylindrical punctures to yield more moths than the largest slit punctures. This tendency was noticed in mass production, although there were exceptions from time to time.

OTHER FACTORS.—The punches not only determined the dimensions and shape of the punctures but they also produced other physical characters which were more or less correlated with moth populations.

The cylindrical punches cut a disc of potato skin and carried it to the bottom of the puncture. The flesh immediately under the disc was compressed in proportion to the depth of the puncture. Most larvae entered the potato around the edge of the skin disc at the bottom of the puncture. Probably this disc was the factor which caused the populations of the two depths to be nearly the same, table 1.

Table 1.—Effect of depth, shape, and diameter of puncture on potato tuber moth populations in 16 potatoes per category.

SHAPE	DEPTH OF PUNCTURE	NUMBER MOTHS PER DIAMETER OF PUNCTURE 0.5 mm.	1.0 to 1.5 mm.	2.5 to 2.7 mm.	TOTALS FOR SHAPE AND DEPTH	TOTALS FOR SHAPE
Taper	2 mm.	238	638	567	1433	
	5 mm.	453	552	665	1654	3087
Cylinder	2 mm.	374	596	702	1673	
	5 mm.	368	597	647	1612	3285
Slit[1]	2 mm.	405	395	406	1206	
	5 mm.	380	472	709	1651	2767
Totals for diameter		2118	3240	3697	—	—
Totals for depth		2 mm. depth—4312 5 mm. depth—4827				

[1] See text for measurements.

The punches for the taper and slit punctures broke the potato skin into a series of scallop-like flaps and tightly pressed them around the edges of the puncture. The flesh was forced apart and the disc of skin was lacking at the bottom of these two types of punctures.

The puncture characters listed in table 1 roughly determine the area of the potato cortex in shallow punctures, and of the cortex and pith in deeper punctures, that is available to the tuber moth for direct entry into the potato flesh. Within certain limits, as the data for diameters in table 1 show, an increase of the area inside the puncture will increase the number of larvae which will enter the potato flesh.

In addition to these physical characters,

the healing of the punctures produced physical changes which affected moth populations. The area of the puncture which offers the larvae direct access to the potato flesh is decreased to varying degrees by the puncture walls resulting from healing which occurs at all humidities. The texture of the wall may be uniformly soft, or uniformly hard, or it may vary from hardness around the top of the puncture to softness at the bottom. Both thickness and hardness of the wall are modified by the age and variety of potato. Hardness may be correlated to a degree with air movement within the tray and with lower humidities. Time is also a factor affecting the hardness of the healed tissue.

The position for larval entry into the potatoes from the taper and slit punctures was either at the edges of the puncture just under the potato skin, at the bottom of the puncture, or somewhere between these two positions. In general, the edge or bottom was used most frequently. In the first white rose potatoes dug in the spring, 50 per cent of the entries were made at the edge of the punctures while the other entries were divided between the side and bottom of the punctures. In potatoes dug 2 weeks later, 50 to 85 per cent of the entries were made at the bottom of the punctures where the walls were soft or healing had not occurred.

When the larva was able to cut a hole through the healed walls of the puncture, its rim thickened until an irregular, hard lump of tissue was formed behind the puncture wall. The mass developed around a smooth round hole which was of the diameter of the hole made by the larva in the wall; this hole led to the tunnel in the soft flesh. The thickness of this mass was sometimes 2 or 3 mm. or even thicker. Frequently the larva in White Rose cut a tunnel entrance through the healed wall of the puncture but did not enter the flesh for a time. During this period, which was 2 to 5 days in length, the mass of thickened tissue with its round hole leading to the flesh, appeared where the future tunnel in the flesh would begin.

The position of entry of the tuber moth larvae in the deep slit punctures was usually near the bottom. It was here that the tissue was more leathery than it was around the edge of the puncture. When the healed tissue at the bottom was fused, a cleavage line was usually present in its structure so that the two triangle-shaped walls which lined the slit, broke apart easily. If there was no fusing at the bottom of the puncture, an unhealed area was accessible to the larva for entry into the flesh.

The healed tissue walls around slit punctures 2 mm. deep were more completely healed and of more uniform thickness than in the deeper punctures.

Healing in taper punctures was similar. Frequently the tissue at the bottom of punctures 2 mm. deep healed completely while the walls of the deeper punctures formed a hard cone to the unhealed bottom.

At times the healed tissue of punctures 2 mm. deep was so hard that moth larvae were unable to establish themselves; at the same time they became established in deeper punctures. Such observations were made not only in white rose potatoes which are highly resistant to tuber moth entry, but also in russets which are the least resistant. Occasionally tuber moth larvae failed completely to become established in whole trays of white rose potatoes because of the hardness of the healed puncture walls. At times the healed tissue warped and the larvae were able to enter the potatoes behind it.

PHYSICAL EFFECT OF PUNCTURES ON PARASITISM.—The effect of the characters of punctures on parasitism of the tuber moth by *Macrocentrus ancylivorus* is both indirect and direct. The indirect effects are correlated with the variability of the moth population which is associated with the physical characters of the puncture. This can be observed in table 2 where a change in moth population was apt to result in a corresponding change in the parasite population. This correlation was particularly true for the shallow punctures and was weaker for the deeper punctures. The data for table 2 also indicate some direct effects of the dimensions of the puncture on parasitism.

DEPTH OF PUNCTURE (PARASITES).—An analysis of variance did not show any significant differences in the actual numbers of *Macrocentrus ancylivorus* obtained at the 2 and 5 mm. depths but there was considerable difference in the per cent parasitization (Table 2). Apparently larger numbers of tuber moth could be

found by the parasites at the 2 mm. depth than at the 5 mm. depth.

DIAMETER OF PUNCTURE (PARASITES).—The relationship of the diameter of the puncture to parasitization of the tuber moth larvae is rather complex as table 2 indicates. When only grand totals for shapes are considered, there were no sharp differences in the per cent parasitization, but smaller numbers of *Macrocentrus ancylivorus* were bred from potatoes with slit punctures. This is the same trend noted previously in the preliminary experiments described in the introduction.

SHAPE OF PUNCTURE (PARASITES).—When the per cent of parasitization for the shape of puncture is considered independently of depth and diameter by the grand totals given in table 2, it had little or no effect upon parasitization.

OTHER PHYSICAL FEATURES.—Hundreds of trays of potatoes infested with tuber moth larvae have been inoculated with 50 to 400 female *Macrocentrus ancylivorus* and the highest parasitism was 97 per cent. The average for white rose was 90 per cent for new potatoes but as the potatoes became older the average percentage parasitization decreased. The data were similar for other varieties but the average parasitism was lower than for white rose. This variability in parasitization is probably correlated with some variable physical feature of the puncture which interferes with finding the tuber moth larvae by the parasite.

One example of physical protection was the reduction of the per cent parasitization by the depth of the puncture.

There were other physical impediments

Table 2.—The effect of depth, shape, and diameter of puncture in potato on the populations of tuber moth and *Macrocentrus ancylivorus* in 5 potatoes per category.

DIAMETER OF PUNCTURE	INSECT	SHAPE OF PUNCTURE: Taper	Cylinder	Slit[1]	GRAND TOTAL FOR DIAMETER
		Punctures 2 mm. deep			
0.5 mm.	No. moths[2]	124	229	291	644
	No. *M. a.*	79	148	147	364
	% *M.a.*	64%	64%	47%	56.5%
1.0–1.5 mm.	No. moths	384	261	243	888
	No. *M. a.*	200	143	154	497
	% *M. a.*	52%	55%	63%	55.9%
2.5–2.7 mm.	No. moths	324	347	186	857
	No. *M. a.*	190	171	116	116
	% *M. a.*	58%	50%	62%	62 %
Grand totals for 2 mm. depth	2389 moths	1338 *M. a.*	56.0% *M. a.*		
		Punctures 5 mm. deep			
0.5 mm.	No. moths	294	227	258	779
	No. *M. a.*	122	110	121	353
	% *M. a.*	41%	48%	47%	45.3%
1.0–1.5 mm.	No. moths	338	338	264	940
	No. *M. a.*	131	138	129	398
	% *M. a.*	38%	42%	49%	42.3%
2.5–2.7 mm.	No. moths	365	307	416	1088
	No. *M. a.*	154	91	211	456
	% *M. a.*	42%	30%	50%	41.7%
Grand totals for 5 mm. depth	2807 moths	1207 *M. a.*	43.4% *M. a.*		
Grand totals for shapes	No. moths	1829	1809	1658	—
	No. *M. a.*	876	801	868	
	% *M. a.*	47.9%	44.3%	52.3%	

[1] See text for measurements.
[2] No. moths = Moth pupae + *M.a.* cocoons.

to parasitization of the moth larvae. The larval populations in the slit punctures of the preliminary experiments were given a degree of protection because 15 to 40 per cent of the punctures were complete closed by the flaps of skin around the punctures' edges. Sometimes the flaps became sufficiently stiff so that any larvae within the puncture was protected from the female parasite as long as it did not cut a hole through the skin.

Those moth larvae which happened to enter the potato so that their tunnel entrance was under a flap of skin were offered a considerable degree of protection from the parasite.

The rate at which the larvae entered the potato flesh itself, and the orientation of the larval tunnel within the potato flesh are other features which give various degrees of protection to the tuber moth larvae from the parasite.

SUMMARY.—The characteristics of the puncture made in the potato for the entry of the tuber moth larvae have an effect upon the number of tuber moths and *Macrocentrus ancylivorus* bred in the potatoes. An increase of the diameter of the puncture from 0.5 to 1+ mm. increases the population of moths significantly, while an increase from 1+ to 2.6 mm. had variable effects. The depth of the puncture affected the moth population with certain combinations of shape and diameter. The shape of the puncture had some effect upon populations.

At times the healing of the puncture affected the moth populations. Also, the way in which the punch cut the skin of the potatoes probably had an effect upon moth populations.

Depth of puncture did not affect the numbers of parasites but did influence the percentage of parasitization. Shape and diameter had no effect upon parasitization.

The closing of the slit punctures with flaps of potato skin by the action of the punch reduced parasitism and the rate of larval entry into the potato flesh and the orientation of the larval tunnel had effects upon parasitization.—4-8-46.

LITERATURE CITED

Finney, Glenn L., Stanley E. Flanders, and Harry S. Smith. 1944. The potato tuber moth as a host for mass production of *Macrocentrus ancylivorus*. JOUR. ECON. ENT. **37**: 61–4.

Smith, Harry S. 1945. Cost of producing *Macrocentrus* by the potato-tuber-moth method. JOUR. ECON. ENT. **38**: 316–9.

Insect Damage and Germination of Seed Treated with DDT

M. D. FARRAR[1] and J. M. WRIGHT,[2] *Illinois Natural History Survey, Urbana*

In the seed trade it is now a common practice to treat seed stocks with a material containing a fungicide. The fungicides have been applied for the purpose of protecting the young plants from seedling diseases. Some of the chemicals employed also give a fair degree of protection against insect damage to the dry seeds during storage.

Soon after the introduction of DDT, preliminary tests indicated that this chemical could be easily adapted for use in a seed treatment. Live stored grain insects were introduced into kilogram samples of wheat and corn previously treated at the rate of 1 ounce per bushel of seed with dusts containing 5 per cent or more of DDT. Insects caused no damage in the treated samples after 2 years of storage. As a further check full bushel samples were stored in burlap bags in a room heavily infested with stored grain insects. Within 9 months the insects had destroyed the untreated grain, leaving untouched the grain treated at 1 ounce per bushel with a dust containing 5 per cent DDT. As a seed treatment, DDT gave excellent protection against insects and apparently did not affect germination.

A wide variety of seeds was used in the present tests, including some of the more popular hybrid sweet and field corn lines

[1] Research Entomologist.
[2] Assistant Entomologist.

of breeding material. Some of these lines have either weak or strong germination characters, and in using DDT on these lines at several levels of concentration, critical information on germination as well as insect control could be obtained. Ability to germinate after storage and damage inflicted by insects are of special interest in lines of known pedigrees and growth characters.

All seeds were weighed into 100-gram samples, treated, and placed in small paper bags left open at the top. As a control, 25 per cent of the bags were left untreated. Treatments were 20 per cent, 10 per cent, 5 per cent, 2.5 per cent, 1 per cent and 0.5 per cent DDT in *Pyrax* applied at the rate of one ounce per bushel. The controls and treated samples were stored together for a year in a room where grain insects were abundant. In this manner the insects had a free choice among the bags, both treated and not treated, and the uniform distribution of untreated bags among the treated bags made it certain the insects were in or near all of the treated samples. Most treatments were replicated two to four times or more. However, with some varieties a shortage of seed necessitated single treatments.

Throughout the year the samples were subjected to severe attack by the insects escaping from breeding cultures maintained within the storage room. At

Table 1.—Per cent damage by insects to all seeds included in the tests, arranged according to the destruction of the untreated controls.

Variety of Seed	Number of Tests		Percent of Seeds Damaged after Treatment with DDT at Concentrations of—						
	Treatment[1]	Control	20	10	5	2.5	1	0.5	Control
Wheat	4	8	0	1.3	2.5	5.3	59.8	92.8	100.0
Sweet corn	8	14	0.5	1.0	5.1	11.2	46.3	78.8	98.8
Barley	2	4	.5	1.5	2.0	7.5	35.0	75.0	97.8
Field corn	20	32	2.3	3.4	4.5	4.9	13.9	40.5	84.3
Squash	1	2	1.0	0	0	0	6.0	32.0	62.0
Popcorn	2	4	0	0	0	0	1.0	7.5	37.0
Mung beans	2	2	0	0	1.0	5.0	7.0	—	30.5
Lettuce	2	4	1.0	1.5	3.5	2.5	4.0	6.0	14.8
Beans	4	7	.8	.5	.8	.5	0	1.0	7.1
Muskmelon	1	1	1.0	1.0	0	1.0	0	1.0	6.0
Cucumber	2	4	0	0	.5	1.5	1.5	1.0	5.8
Oats	2	4	0	0	0	0	0	1.5	5.5
Watermelon	2	4	0	0	0	1.0	2.0	4.5	5.5
Tomato	2	4	0	0	.5	0	0	2.5	5.3
Peas	3	5	0	0	1.3	.3	1.0	2.0	3.4

[1] One treatment consists of six individual samples, one sample treated with each concentration of dust.

Table 2.—Per cent damage by insects to some field corn, sweet corn and popcorn inbreds and hybrids treated with DDT.

Variety of Corn	Number of Tests		Percentage of Seeds Damaged after Treatment with DDT at Concentrations of—						
	Treatments	Control	20%	10%	5%	2.5%	1%	0.5%	Control
Field corn WF9	2	3	2.5	3.0	5.5	5.0	23.5	69.0	98.7
R30 (1944)	3	5	2.3	6.3	7.3	7.0	23.7	55.0	96.8
WF9×38-11	2	3	.5	0	1.0	2.0	8.5	48.0	93.0
Illinois 201	4	8	.3	.3	1.0	1.5	5.8	34.0	86.6
Waxy Hy	4	8	3.8	6.5	7.8	7.3	8.5	28.8	81.9
Sweet corn Golden Cross J5H913	2	4	.5	1.5	3.0	14.0	35.0	79.5	100.0
Bantam (Burpee Single Cross)	2	4	0	.5	3.5	14.5	45.5	70.5	99.5
Popcorn (30×16) (18×24)	2	4	0	0	0	0	1.0	7.5	37.0

the end of the experiment the insects were killed by freezing. Each sample was then screened of dead insects and foreign material and a count was made of the damaged kernels to determine the percentage of injured seeds.

Species of insects found in the infested seeds were the Indian meal moth, *Plodia interpunctella* (Hbn.), confused flour beetle, *Tribolium confusum* Duv., red flour beetle, *T. castaneum* (Hbst.), flat grain beetle, *Laemophloeus minutus* Oliv., sawtooth grain beetle, *Oryzaephilus surinamensis* (L.), granary weevil, *Sitophilus granarius* (L.), rice weevil, *Sitophilus oryza* (L.), and the lesser grain borer, *Rhizopertha dominica* F.

Only those seeds treated with dusts containing 5 per cent, 10 per cent, and 20 per cent DDT dusts were germinated. Those samples treated with dusts containing less than 5 per cent DDT had sufficient insect-damaged kernels to make a germination test unreliable. All of the samples were germinated at one time, using a standard method in an approved germinator. A germination sample consisted of 100 seeds.

DISCUSSION.—Under the conditions of the experiment, the most heavily damaged grain was wheat, followed in order by sweet corn, barley, field corn, squash, popcorn, mung beans, lettuce, stringbeans, muskmelon, cucumber, oats, watermelon, tomato, and garden peas.

The amount of insect damage to the untreated controls was used as a basis for arranging the data given in table 1. In this table are data on the protection afforded all types of seeds by the six concentrations of DDT dusts. It can be noted that a sharp break in protection occurs between the dusts containing 2.5 per cent and 5 per cent DDT. Some degree of control is shown at all levels, but 2.5 per cent DDT appears to be the lowest practical concentration under the conditions of these tests.

Only very slight differences in insect damage appeared between varieties of sweet corn, as shown in table 2. Differences in amounts of damage to several field corn inbreds and hybrids were greater than in sweet corn and indicated that some lines are more favorable to insect-attack than others. Further data must be accumulated, however, before any definite conclusions can be drawn.

No apparent reduction in ability to germinate after treatment with DDT was shown by a variety of seed in these tests. Only small and inconsistent differences were noted between treatments of 20 per cent, 10 per cent, and 5 per cent dusts. In many instances germination was higher in seed treated with 20 per cent dust than in that treated with the 10 per cent or 5 per cent dusts. No comparisons could be made between treated and untreated seed since it was impossible for untreated seed to remain free of insects for a year under the conditions of this experiment.

SUMMARY.—Dusts containing DDT, when used at one ounce per bushel on 15 kinds of seeds, protected them from attack by 8 species of stored grain insects. Dusts that contained from 2.5 per cent to 20 per cent DDT gave excellent protection. Dusts with less than 2.5 per cent DDT were not completely effective. Seeds that had been treated with dusts containing 5 per cent, 10 per cent, and 20 per cent DDT grew satisfactorily when tested in a standard seed germinator.—5-27-46.

LELAND WOLFE DIES

"Leland Wolfe, Leader of the Quarantine Vehicular Inspection Section, Japanese Beetle Project, U.S.D.A., died September 8. He was stationed at East Orange, N. J. He had been acutely ill since the latter part of May. He was born in Dayton, N. Y. April 24, 1897. Mr. Wolfe first entered the Bureau of Entomology and Plant Quarantine in 1924, when he was assigned to the European Corn Borer Project. He supervised scouting, control and quarantine activities in various locations in New York State before being transferred to the Japanese Beetle Project. He served as Leader of both the Syracuse, N. Y. and New York City regional offices of the latter project. He was active in the New York City USDA Club, having served as Secretary during 1941–42. He also served in the U. S. Navy in World War I."

WILLIAM MIDDLETON

Cryolite for Codling Moth Control in the Pacific Northwest

F. P. Dean, E. J. Newcomer, and W. E. Westlake, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Fluorine compounds are widely used as insecticides, and much work has been done on them as substitutes for lead arsenate in controlling the codling moth, *Carpocapsa pomonella* (L.). The first work on this problem under arid conditions was done by the Bureau of Entomology and Plant Quarantine at Yakima, Wash., in 1925. Newcomer & Carter (1933) published the results of work done through 1930, concluding that barium fluosilicate, potassium fluosilicate, and sodium fluoaluminate (cryolite) might be used in place of lead arsenate, and that a sticker such as fish-oil or mineral-oil emulsion should be used with them.

After the publication of an article (Newcomer 1931) suggesting the use of fluorine compounds in the arid regions of the Pacific Northwest and indicating that barium fluosilicate and cryolite were available, fruit growers began using these materials. They were also recommended by the State College of Washington (1932) in 1932. Since then the use of cryolite in Washington has increased steadily, and in 1944 nearly 5,500,000 pounds were used as compared with about 11,300,000 pounds of lead arsenate.[2]

A number of questions arose from time to time as to which fluorine compound was the best, what type of sticker should be used with it, whether the fluorine compound could be used more advantageously early in the season than late, and whether a cheaper cryolite containing only 70 per cent of fluorine could be used in place of the 90 to 95 per cent material. All the work reported in this paper was done with natural cryolite.

Experiments made from 1931 to 1933, although on a limited scale and not replicated, showed rather definitely the superiority of a finely divided cryolite over potassium or barium fluosilicate. In 1934 replicated tests were made to determine the value of various stickers when added to cryolite. Each test was applied to 2 Jonathan apple trees and to 2 groups of 2 trees each of the Winesap and Rome varieties. The average results from these 10 trees are shown in table 1. Cryolite without any sticker was not successful, and the addition of soybean oil, while it improved the control somewhat, did not make cryolite equal to lead arsenate. Dogfish oil, a liquid colloidal spreader containing oil, tar soap, and emulsified mineral oil all produced satisfactory results, not differing significantly from those obtained with lead arsenate and emulsified mineral oil.

Table 1.—Comparative efficiency of various stickers when added to cryolite for control of the codling moth, 1934.

Treatment (Quantity per 100 gals.)	Number per 100 Apples	
	Worms	Injuries
Cryolite 3 lb.	44.1	125.5
Cryolite 3 lb. plus:		
Soybean oil 1 pt.	25.4	86.2
Dogfish oil 1 qt.	18.9	53.7
Colloidal spreader 1 qt.	14.7	54.7
Tar soap 0.25 lb.	17.0	65.6
Mineral oil (emulsified) 3 qts.	16.1	52.3
Lead arsenate 3 lbs., mineral oil (emulsified) 3 qts., (check)	19.5	63.6

In 1933 the U. S. Food and Drug Administration set a tolerance of 0.01 grain of fluorine per pound of fruit, and in 1938 this tolerance was increased to 0.02 grain per pound. In order to meet either tolerance, growers could use cryolite only part of the season. Tests were made in 1938 to determine whether the time of use would make any difference in control. The treatments consisted of cryolite and lead arsenate, each at 3 pounds per 100 gallons, plus 1 pint of fish oil-soap. As shown in table 2, there was no significant difference in the control obtained by using lead arsenate in the first-brood sprays and cryolite in the second-brood sprays, and cryolite in the first-brood sprays and lead arsenate in the second-brood sprays, and neither program gave results significantly different from those obtained by using lead arsenate throughout the season.

[1] Acknowledgement is due to C. C. Cassil, formerly of this Bureau, who made the chemical analyses in 1943.

[2] Figures obtained from Washington State Department of Agriculture.

Table 2.—Comparative efficiency of lead arsenate and cryolite in codling moth control, 1938.

Treatment	Number per 100 Apples					
	Orchard A		Orchard B		Orchard C	
	Worms	Injuries	Worms	Injuries	Worms	Injuries
Lead arsenate throughout season	14.8	68.7	2.3	10.0	71.8	199.4
Lead arsenate for first brood, cryolite for second brood	12.0	52.0	4.3	15.8	47.7	134.9
Cryolite for first brood, lead arsenate for second brood	14.5	57.0	2.5	10.5	54.0	141.9
Difference required for significance at odds of 19:1	11.9	53.8	4.1	17.5	24.3	83.7

Table 3.—Comparative efficiency of lead arsenate and cryolite in codling moth control, 1943. Insecticide 3 lb., mineral oil (emulsified) 1 qt. colloidal spreader 1/6 lb., plus toxic ingredient, as indicated.

Treatment	Number per 100 Apples		Average Spray Residues,[1] in mg./sq. cm.		
	Worms	Injuries	Before spraying	After spraying	Harvest
Lead arsenate	6.2	12.0	20.1	40.2	22.9
Cryolite:					
90 per cent	7.3	25.6	28.7	50.0	42.1
70 per cent	7.8	22.8	27.6	54.8	53.2
Differences required for significance at odds of 19:1	2.5	6.3	—	—	—

[1] Residues in lead arsenate treatment As_2O_3, and in cryolite treatments F.

During the war there was some doubt about getting enough cryolite, and a somewhat less refined material was tested. The material used in 1943 contained not less than 70 per cent and in 1944 not less than 75 per cent of sodium fluoaluminate, according to the labels. The standard material, used for comparison, was guaranteed to contain not less than 90 per cent of sodium fluoaluminate.

A limited test was made in 1943, using each material at 3 pounds to 100 gallons (Table 3). The less refined material seemed to adhere to the fruit better than the standard material. Average fluorine residues during the season, as determined by analyses made before and after each cover spray, and also at harvest, were slightly higher for the 70 per cent material. There was no significant difference in control, in terms of worms per 100 apples, between the two cryolites or between them and the lead arsenate. More stings resulted from both cryolites, and in terms of total injuries they were significantly less effective than the lead arsenate. This is contrary to the usual experience with cryolite, and no explanation for it is known except that the deposits of fluorine on the apples were slightly less than in other years.

In 1944 the tests were repeated on a larger scale (Table 4), and this time there was no significant difference in any of the tests between the two cryolites or between them and the lead arsenate. The fluorine and arsenic residues maintained during the season are shown in figure 1. There was not much difference in the average deposit from the 90 per cent and 75 per cent cryolites (Nos. 2 and 3, respectively). The tolerance for fluorine was increased to 7 parts per million (approximately 0.05 grain per pound) in 1944, which increase permitted growers to use it in a larger number of applications than before.

Throughout the period of testing

cryolite on apples, records were kept of the average size of the apples from the various sprayed trees in terms of the average number of apples per picked box. Since both the size on individual trees and the contents of a picked box may vary, this method would probably not

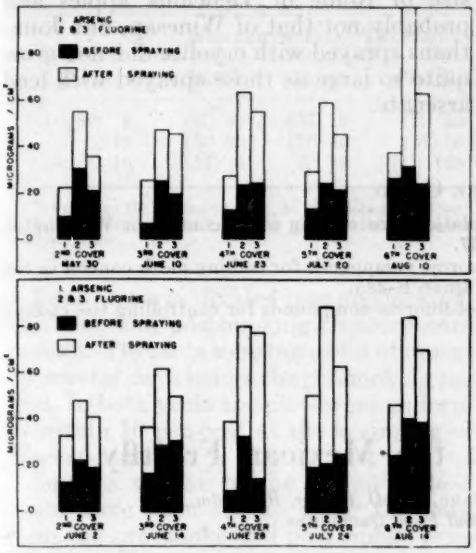


FIG. 1.—Deposit of arsenic and fluorine maintained on apples, 1944. (See table 4 for treatments.) Above, Winesaps; Below, Romes.

detect slight differences, but any very marked effect on size would appear. Table 5 shows the average number of apples per box for all trees having a full crop that were sprayed with cryolite from 1931 to 1944, and for an equal number of comparable trees sprayed with lead arsenate during the same years. Rome and Delicious applies have a tendency to grow large, and there is no evidence in these averages of any effect of cryolite on the size of these varieties. Winesap apples have a tendency to remain small under adverse conditions. The averages shown indicate that cryolite may possibly have a slight effect on the size of this variety. Jonathans show a more marked difference, being slightly smaller when sprayed with cryolite. Lead arsenate was employed as a standard in this comparison because it is the material most widely used for controlling the codling moth. No comparison with unsprayed fruit could be made because such fruit would become wormy and so much of it would drop prematurely that the normal size could not be determined. Whether lead arsenate affects the size is not known.

SUMMARY.—Investigations of fluorine compounds made by the U. S. Bureau of Entomology and Plant Quarantine have

Table 5.—Size of apples resulting from applications of cryolite and of lead arsenate for period 1931–1944.

VARIETY	NUMBER OF TREES SPRAYED WITH EACH	AVERAGE NUMBER OF APPLES PER BOX AFTER TREATMENT		PER CENT DIFFERENCE IN SIZE
		Lead arsenate	Cryolite	
Rome	53	104	105	1
Delicious	21	101	102	1
Winesap	27	138	143	4
Jonathan	36	129	138	7

Table 4.—Comparative efficiency of lead aresenate and cryolite in codling moth control, 1944. Insecticide 3 lb., mineral oil (emulsified) 1 qt.,[1] colloidal spreader one-sixth lb., plus toxic ingredient, as indicated.

TREATMENT	NUMBER PER 100 APPLES					
	Orchard A		Orchard B		Orchard C	
	Worms	Injuries	Worms	Injuries	Worms	Injuries
Lead arsenate	16.6	53.1	54.2	142.6	15.5	68.8
Cryolite:						
90 per cent	14.4	55.6	38.2	109.5	18.5	68.6
70 per cent	21.8	67.4	38.2	125.2	17.8	58.7
Differences required for significance at odds of 19:1	10.7	25.0	20.6	44.0	13.5	32.6

[1] Increased to 2 qts., in the second, third, and sixth cover sprays.

shown that cryolite may be used successfully for controlling the codling moth (*Carpocapsa pomonella* (L.)) under arid conditions. They have also shown the need for using a sticker; and dogfish oil, tar soap, a colloidal spreader, and emulsified mineral oil were found to be satisfactory. When cryolite was not used for the entire season, results were equally good when it was used in either the early or late applications. A less highly refined cryolite, containing 70 to 75 per cent sodium fluoaluminate, controlled the codling moth as well as the standard material containing 90 per cent. As a rule, cryolite used at 3 pounds to 100 gallons of spray with 1 or 2 quarts of emulsified mineral oil and a little colloidal spreader resulted in the same control as lead arsenate used in the same manner. It did not affect the size of Rome or Delicious apples and probably not that of Winesap, but Jonathans sprayed with cryolite did not grow quite so large as those sprayed with lead arsenate.

LITERATURE CITED

Washington State College. 1932. Spray recommendations for codling moth control in Washington for 1932. Wash. Agr. Expt. Sta. Ext. Bul. **167.**

Newcomer, E. J. [1931.] Suggested use of certain fluorine compounds for codling moth control in the Pacific Northwest. U. S. Bur. Ent. and Plant Quar. **E-285.**

Newcomer, E. J., and R. H. Carter. 1933. Studies of fluorine compounds for controlling the codling moth. U. S. Dept. Agr. Tech. Bul. **373.**

The Effect of Smoke on the Mexican Fruitfly

JOHN G. SHAW and DONALD F. STARR, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Residents in Cuernavaca, Morelos, Mexico, have occasionally mentioned that daily smoking of mango trees during the fruit-maturing season reduced the percentage of fruit infested by the Mexican fruitfly, *Anastrepha ludens* (Loew). One fruit buyer stated that smudged groves produced only about half as much infested fruit as unsmudged groves.

Several tests were made in the Borda Garden in Cuernavaca to study the reduction in the number of fruitflies caught in traps placed in smudged groves over the number caught in unsmudged groves. Small plots of two or three large mango trees with closely grown canopies were selected. Ten standard glass fruitfly traps (McPhail 1943) were located in each plot. The trap locations were marked so that the traps could be rehung in their respective places after examination. The lure used in the traps was a fermenting solution containing 80 grams of granulated sugar and 1.5 grams of dried beer yeast, with water added to make 1 liter. This is essentially the formula developed by McPhail (Baker *et al.* 1944). This mixture was held at 22° to 28° C. for about 2 days, or until fermentation became vigorous.

In 1943 only the litter from mango groves, consisting mostly of mango leaves, was used in producing the smudge of smoke. The studies were made during the season of frequent rainfall; therefore, the litter was usually very damp and it was rather easy to keep the piles smoldering. This was important, because records had shown that the temperature would rise appreciably if the litter was allowed to burst into flame. From 3 to 5 piles of smoldering litter were kept ignited and were moved occasionally when air currents changed. In this way it was possible to keep smoke rising into the trees. A switchback design was used, and each plot served alternately as test or control.

The same trees and trap locations used in 1943 were chosen for plots 1 and 2 in 1944, and additional trees were selected for a third plot. Mango leaves and rice straw were burned separately in the treatment of 2 of the plots, while the third plot was untreated. Before the dry rice straw was ignited it was heavily sprinkled with water. A 3 by 3 latin square was the design used in shifting the tests chronologically (Table 1). The numbers recorded are the totals from 10 traps. The square was

constructed with one dimension in space and the other in time. The usual columns were replaced by locations or plots, and rows became periods.

Table 1.—Mexican fruitflies captured (10 traps per plot) in the presence of smoke, in mango trees in Cuernavaca, Morelos, 1944.

Date	Number of Flies Trapped[1]		
	Plot 1	Plot 2	Plot 3
August 4	(U) 97	(M) 14	(R) 40
10	(R) 20	(U) 56	(M) 16
16	(M) 4	(R) 13	(U) 125

[1] U indicates the untreated plots, M the plots treated with smoke from mango leaves, and R the plots treated with smoke from rice straw.

Each test was divided into presmoking, smoking, and postsmoking trap-exposure periods. The plots were tested for uniformity several days before the presmoking period. In both years the plots were uniform to within 10 per cent at the beginning of the experiments.

Squares similar to the one in table 1 could have been set up using the data from the pre-smoke and post-smoke periods, but the results indicating the repellent effect of the two smokes in the complete 3 by 3 latin-square experiment were combined and summarized in table 2. The data obtained in 1943 and in the first trial of 1944 with smoke from mango leaves were not included, but the reduction was 83 and 84 per cent in two complete switch-back experiments in 1943, and 94 per cent in the first trial in 1944. The 88 per cent reduction in table 2 is in good agreement.

In all three comparisons the smoke from the mango leaves seemed to be more repellent than the smoke from rice straw, but the 3 by 3 square was too small to establish the difference as statistically significant. The difference in the results of the treatments was definitely significant, but this seemed to be due entirely to the lower catches in the smoked plots than in the unsmoked ones.

The smoke affected the catch for 1 day following the treatment, and the effect of one of the smoke treatments was noticeable for at least 3 days. The difference probably was due to the activity of the flies returning to build up a normal population in the smoked tree.

The numbers of male and female flies of

Table 2.—Repellent effect of smoke from mango leaves and rice straw on the number of Mexican fruitflies captured in mango trees in Cuernavaca, Morelos, 1944.

Period	Number of Fruitflies in Untreated Trees	Number of Fruitflies in Trees Treated with Smoke from—		Per Cent Reduction on Trees Treated with Smoke from—	
		Mango Leaves	Rice Straw	Mango Leaves	Rice Straw
Pre-smoke, 1 day	399	429	367	—	—
Smoke,[1] 1 day	278	34	73	88	74
Post-smoke:					
1 day	406	314	301	23	26
2 to 4 days	1,152	1,145	1,163	—	—

[1] Actual smoking of trees continued for approximately 9 to 10 hours, from about 8 a.m. to 6 p.m., the time of day when flies are active and enter traps (McPhail 1937).

Anastrepha ludens recorded in traps on days during smoking tests in 1944 were approximately equal.

In laboratory tests smoke definitely affected the fruitflies, even killing them in one test.

Tests on the effect of smoke were made with 25 pairs of laboratory-reared flies confined in cages measuring approximately 12 by 12 by 12 inches. Three sides of each cage were made of muslin, and the front panel and cover were of glass. Mango leaves were wrapped in a piece of white paper to form a cylinder. The end of the cylinder was ignited, and smoke was blown into a cage of flies for about 30 seconds, or long enough to fill the cage with smoke. The flies became agitated immediately and moved around in small areas in a jerky manner. Within a few minutes they became less active than flies in the control cage, and about 90 per cent were rubbing their bodies with their legs, as if trying to clean themselves. In the control cage about 10 per cent of the flies appeared to be cleaning themselves. Within 30 minutes most of the test flies were still rubbing themselves vigorously but had also started to move around more actively. At the end of 60 minutes the activity of the test flies was about normal. By this time the visible smoke had dissipated through the muslin sides of the cage, but the odor of burnt mango leaves still remained. At 6:15 p.m., 8 hours after smoke had been introduced into the cage, 3 pairs of flies were copulating in the test cage and the same number in the control cage. Similar results were noted in a second test with another stock of flies. In this

second test it was observed that more flies in the test cage than in the control cage regurgitated, especially during the first 10 minutes after smoke had been introduced.

In another test only 20 flies were confined in a cage and a greater amount of smoke from burning mango leaves was introduced, the smoking being continued until the last fly dropped from the glass top of the cage. Within 6 minutes after the smoking was stopped 3 flies had recovered enough to be able to walk, and 11 minutes later 19 of the 20 flies had recovered. The next morning, about 13 hours later, all the flies appeared to be in normal condition.

Groups of 5 pairs of flies were confined in each of three 2-liter Erlenmeyer flasks. Smoke from mango leaves was introduced into two of these and all were stoppered with corks. Within 75 minutes all flies in the smoke-filled flasks had fallen to the bottom and were partially paralyzed. When examined the next morning, about 13 hours later, all flies confined with smoke were dead, while those in the control flask appeared to be normal.

The laboratory tests indicated that the fruitflies in the mango trees were merely excited and driven out, since much higher concentrations of smoke in the laboratory did not kill the flies.

The behavior of caged flies toward smoke from rice straw was similar. It is rather surprising, however, that there was not a greater difference between the results from burning rice straw and those from mango leaves. A. C. Baker had suggested that one might expect the smoke from mango leaves to be more effective in the field, since *Mangifera*, the genus to which mango belongs, is closely related to *Anacardium*, *Schinus*, *Comocladia*, *Metopium*, *Pseudosmodingium*, and *Rhus*, all of which, including mango, are reported to be poisonous in one form or another. In India the oil obtained from the cashew nut, *Anacardium*, is applied to the floor and rafters of houses to protect them from insect attack (Standley 1923).

No record was kept of the infestation of mangoes in trees that were smoked. Apparently, however, protection of the mangoes would require smoking for many days, and the value of the crop probably would not justify the expense.

SUMMARY.—Experiments showed that smoke from burning mango leaves, and also from rice straw, greatly reduced the number of fruitflies captured in mango trees in Cuernavaca, Morelos, Mexico. In one experiment the effect of smoke lasted 3 days. The experiment was designed as a 3 by 3 latin square in space and time.

Caged flies became agitated immediately upon exposure to smoke produced by burning either mango leaves or rice straw, and during several minutes many regurgitated. This was followed by constant rubbing of their bodies with their legs. After about an hour, the time required for smoke to leak through the muslin-covered cage, the flies resumed normal activity. Flies held in stoppered flasks with smoke from mango leaves were dead within 13 hours.

Although no records were kept on the infestation of mangoes in trees that were smoked, the slight residual effect of smoke would indicate that continued smoking for many days would be necessary to protect fruit on trees.—5-7-46.

LITERATURE CITED

Baker, A. C., W. E. Stone, C. C. Plummer, and M. McPhail. 1944. A review of studies on the Mexican fruitfly and related Mexican species. U. S. Dept. Agr. Misc. Pub. **531.**

McPhail, M. 1937. Relation of time of day, temperature and evaporation to attractiveness of fermenting sugar solution to Mexican fruitfly. JOUR. ECON. ENT. **30**(5): 793–8.

McPhail, M. 1943. Linseed oil soap—a new lure for the melon fly. JOUR. ECON. ENT. **36**(3): 426–9.

Standley, P. C. 1923. Trees and shrubs of Mexico (Oxyalidaceae-Turneraceae). U. S. Natl. Mus. Contrib. U. S. Natl. Herbarium **23**(3): 655–72.

Dr. Donald F. Starr, a former member of the Bureau of Entomology stationed in Mexico, and a contributor to the JOURNAL, resigned in 1945 and is now a member of the staff of S. B. Penick & Co., at 50 Church St., New York 7.

Randall Latta, of the Bureau of Entomology and Plant Quarantine, has recently changed his headquarters from his former station in Washington, D. C. to El Paso Texas, where he may be addressed at 127 U. S. Courthouse.

Toxicity of Nitriles to Stored-Grain Insects

R. T. COTTON and H. H. WALKDEN, *U.S.D.A. Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Recent interest in acrylonitrile and trichloroacetonitrile as fumigants led to the testing of a number of related compounds. In estimating the toxicty of the various nitriles, two types of laboratory tests were used, and field tests were made to evaluate the more promising compounds in admixture with carbon tetrachloride.

The laboratory experiments were conducted in empty 20-liter flasks and in 20-liter flasks filled with wheat. Adults of the confused flour beetle, *Tribolium confusum* Duv., and the rice weevil, *Sitophilus oryza* (L.), were used as test insects. All tests were made for a 24-hour-exposure period at a constant temperature af 80° F. and a relative humidity of 70 to 80 per cent. The insects were from 30 to 60 days old, and were taken from cultures reared in whole-wheat flour under the same conditions of temperature and relative humidity at which the fumigation experiments were conducted. Thirty adults of each species were placed in 1.5-ounce gelatin capsules that had both ends removed and covered with pieces of fine silk cloth. Capsules containing the insects to be fumigated were suspended at approximately the middle of the fumigation flask. In order to insure rapid distribution of the fumigant, the pressure in the fumigation flasks was reduced to approximately 600 mm. of mercury, absolute pressure, after which the fumigant was introduced by means of a pipette and the pressure raised to normal. Three replications were made of each test. At the end of the exposure period the capsules were removed from the flasks, and the insects were supplied with fresh food and held at room temperature for 24 hours.The percentage mortality was then determined.

The toxicity of the various nitriles to the confused flour beetle and the rice weevil, under the conditions described, is indicated by the data in table 1, listed in descending order of toxicity to the rice weevil. It is notable that most of these nitrile compounds were more toxic to the rice weevil than to the flour beetle.

[1] The writers are indebted to E. C. Herthel, of the Sinclair Refining Company, East Chicago, Ind., for furnishing supplies of these nitriles.

In tests made in 20-liter flasks filled with wheat, it was found that most of the nitriles were absorbed to such an extent by the surface layer of grain that they did not show promise as grain fumigants. Aside from acrylonitrile and trichloroacetonitrile, which have been discussed in a previous paper (Cotton & Young 1943) 2-chloroacrylinitrile proved to be more toxic in the presence of wheat than were any of the other compounds.

Table 1.—Relative toxicity of various nitrile compounds to rice weevil and flour beetle adults in a 24-hour exposure at 80° F.

Compound	Minimum Dosage Giving 100 Per Cent Kill of—	
	Rice weevil	Flour beetle
	mg. per liter[1]	*mg. per liter*
2-Chloroacetonitrile	0.6	1.2
2,2-Dichloroacetonitrile	.68	3.4
2,2,3-Trichloropropionitrile	.70	2.1
Acrylonitrile	.80	1.21
2-Chloroacrylonitrile	1.0	1.63
Trichloroacetonitrile	1.43	4.29
2,2,3,4-Tetrachlorobutyronitrile	1.46	2.19
2-Chloropropionitrile	1.6	7.49
3-Chloropropionitrile	1.7	2.28
2,2,3-Trichlorobutyronitrile	1.98	1.98
2,2,4-Trichlorobutyronitrile	2.0	2.72
2,2-Dichloropropionitrile	2.42	6.05
2,3-Dichloroisobutyronitrile	3.63	4.84
4-Chlorobutyronitrile	4.4	3.3
3-Chlorobutyronitrile	6.9	6.42
Isobutyronitrile	7.61	11.4
N-Butyronitrile	7.96	7.96
2,2-Dichlorobutyronitrile	11.7	11.7
Propionitrile	11.7	27.4
Acetonitrile	27.39	27.39
2-Chloroisobutyronitrile	8+[2]	8+[2]

[1] Grams per liter × 62.43 = pounds per 1000 cubic feet.
[2] No mortality at this dosage.

Large-scale fumigation tests were conducted in steel bins with this compound and three of the others that appeared to be the most toxic against both species of insects used in the laboratory tests.

For the fumigation of wheat it was found advantageous to dilute highly toxic compounds with carbon tetrachloride, in order to increase their volume sufficiently to insure a uniform distribution over the surface of the grain and a better penetration of the grain mass. Mixtures consisting of 1 part by volume of the nitrile with 9 parts of carbon tetrachloride were applied uniformly over the surface in a coarse spray, at the rate of 1 gallon per 1000 bushels of wheat. Tests were made

in bins of 1000, 2000, and 2740 bushels capacity. The wheat in these bins had a depth of 7, 9, and 12 feet, respectively, and a surface area of 154, 254, and 254 square feet. During the period of the tests grain temperatures ranged from 60° to 80° F.

To determine the toxicity of the various mixtures and the uniformity of distribution through the grain mass, insects were exposed to the action of the fumigants by the use of probes, or "check sticks," composed of dowels 3 feet long, fastened together with perforated sheet-metal sleeves so that a small cell was formed at each union. A metal-cloth cylinder, or cage, was filled with wheat, and insects were placed in each cell. The check sticks could be made any length and were thrust vertically to the bottom of the bins so that insects were exposed at 3-foot intervals from the top to the bottom of the bins. Metal-cloth cylinders containing insects were buried 4 inches under the surface of the wheat in the center and at the four cardinal points of the bin, about 3 feet from the wall. Whenever a bin was fumigated, insects were also planted as a check in a bin that remained untreated. The insects were removed from treated and untreated bins and mortality was determined 72 hours after the fumigants were applied. In the untreated bins insect mortality never exceeded 5 per cent. The total number of insects in each test ranged from 630 to 1153 and included adults of the rice weevil, lesser grain borer, long-headed flour beetle, red flour beetle, flat grain beetle, and saw-toothed grain beetle. The effectiveness of the various mixtures tested is indicated by the data in table 2.

Table 2.—Toxicity of chloronitriles in admixture with carbon tetrachloride (1:9) to stored-grain insects.

Chloronitrile	Bin Capacity (Bushels)	Per Cent Mortality at Floor Level and Above					Total Mortality[1]
		Floor	3 ft.	6 ft.	9 ft.	Grain surface	
2-Chloroacrylonitrile	1000[2]	98	100	100	—	100	100
	2740	98	81	86	92	100	93
2-Chloroacetonitrile	1000[2]	100	97	96	—	100	98
	2740	100	90	97	97	100	97
2,2,3-Trichloropropionitrile	1000[2]	99	92	79	—	100	95
	2740	93	91	93	85	100	93
2,2,3-Trichlorobutyronitrile	1000[2]	100	91	82	—	96	93
	2740	98	81	85	81	100	90
2-Chloroacrylonitrile pilus 2,2,3-Trichlorobutyronitrile (1:1)	1000	100	100	100	—	100	100
	2740	100	100	100	100[3]	100	100
	2740	100	100	100	100	100	100
None (carbon tetrachloride only)	1000[2]	99	92	97	—	95	96
	2740	92	75	92	94	93	90

[1] Based on total number of insects exposed.
[2] Average of two tests.
[3] Mortality at 8-foot level.

It is evident that the addition of 10 per cent by volume of 2-chloroacrylonitrile or 2-chloroacetonitrile to carbon tetrachloride resulted in a slight, though definite, increase in the over-all mortality in both 1000- and 2740-bushel bins, as compared with carbon tetrachloride alone. This was apparently due to the higher mortality obtained in the upper parts of the bins. The belief that better surface kills were obtained with mixtures containing 2-chloroacrylonitrile, whereas better kills at the bottom of the bin were obtained with mixtures containing 2,2,3-trichlorobutyronitrile led to the testing of a mixture of 5 per cent each of 2-chloro-

acrylonitrile and 2,2,3-trichlorobutyronitrile in carbon tetrachloride. It is notable that, oddly enough, perfect kills were obtained with this combination in 1000-, 2000-, and 2740-bushel bins at the same dosage—1 gallon per 1000 bushels.

In our experimental work with the chloronitriles, it was observed that the vapors from 2-chloroacrylonitrile, 2-chloroacetonitrile, and 2,2,3-trichloropropionitrile were noticeably lachrymatory. In handling these compounds care should also be taken to avoid spilling the liquid on clothing or skin, or exposing the perspiring body to the vapors, because severe dermatitis may result from such exposure —4-18-46.

LITERATURE CITED

Cotton, R. T., and H. D. Young. 1943. Acrylonitrile and trichloroacetonitrile in admixture with carbon tetrachloride as possible fumigants for stored grain. JOUR. ECON. ENT. 36(1): 116–7.

The Velvetbean Caterpillar on Peanuts: Control Experiments

L. L. ENGLISH,[1] *Alabama Agricultural Experiment Station, Auburn*

The severe epidemic of the velvetbean caterpillar, *Anticarsia gemmatilis* (Hbn.), on peanuts in southeast Alabama during 1944 afforded an opportunity to conduct further[2] experimental work with this insect.

The main objectives of these tests were: (1) To compare the effectiveness of three cryolite products and DDT; (2) To determine the number of applications of cryolite necessary for the control of the worms and; (3) To determine the optimum time to dust.

METHODS AND PROCEDURE.—A uniform field of runner peanuts was selected for the plots. The treatments were replicated twice and each replicate consisted of 4 rows 70 feet long. A 3-foot alley was run each way between plots. Furrows were run in the center of the alleys, which were re-plowed from time to time to provide a dust mulch in order to prevent migration of worms from one plot to the other. The alleys and furrows proved to be very effective barriers, since the weather was hot and dry during most of the experimental period.

The two outside rows of each plot were used for worm counts. The unit count was made from 2 linear feet of row. The unit was marked off, the vines were cut with a knife and shaken over a cloth. The worms on the cloth and on the ground where the vines were removed were counted. Two unit counts were made from each plot before treatment and at intervals after treatment.

The two inside rows of each plot were used for yield records. The first yield records were taken on September 28, which was about a week after the vines on the check plots were almost completely stripped of leaves by the worms. The second yield records were made on October 9. Two 100-square foot units (33⅓ linear feet of row) were taken from one row in each replicate on each of the above dates. The vines were cut with a horse-drawn tool, pulled up, and shaken free of soil. The peanuts were picked off the vines by hand and weighed separately from those that were scratched out of the ground with a fork. The peanut samples were bagged for drying.

To arrive at a uniform adjustment of yields, samples of peanuts were taken from a shelling plant and dried to constant weight in an oven at 95–100° C. These samples were found to contain 10 per cent moisture. Consequently, the plot samples were dried to constant weight and then multiplied by 1.1 and by 435.6 to give the per acre yield. Samples from the first digging averaged 53.8 per cent moisture, while those from the second digging averaged 43.6 per cent moisture. No association between moisture content and plot treatment could be found. The approximate specific gravity of all sam-

[1] Now with the Illinois National History Survey, Urbana. The author is indebted to J. P. Wilson, Superintendent of the Wiregrass Substation, Headland, Alabama, for expert assistance in carrying out this work.

[2] Guyton F. E. An Outbreak of the Velvetbean Caterpillar in Alabama with Data on Control. JOUR. ECON. ENT. 33: 635–39. 1940.

ples was determined by submerging 100 grams of peanuts in water in a graduated cylinder. No association between specific gravity and plot treatment was found.

According to labels, *Kryocide*, natural cryolite, contained 90 per cent sodium fluoaluminate. *Kryocide D-50* contained 45 per cent sodium fluoaluminate and 23.25 per cent sulphur. *Alorco* cryolite, synthetic cryolite, contained 85 per cent sodium fluoaluminate. These materials were obtained on the open market. The 3 per cent DDT dust was Geigy Company's *Gesarol A-3*.

The dusts were applied at the rate of about 20 pounds per acre when the atmosphere was still, either late in the afternoon or early in the morning. A rotary hand-operated duster was used, with the discharge directed downward towards the tops of the peanuts.

YIELD RECORDS.—Yields taken September 28 show that all treatments, with one exception, were significantly better than the nearest checks (Table 1). This

Table 1.—Yield of peanuts on vines from plots dusted for the control of the velvetbean caterpillar.

TREATMENT	DATE TREATED	POUNDS PER ACRE		
		Sept. 28	Oct. 9	Gain or Loss[1]
Kryocide	August 28	1311	1303	− 8
Kryocide D-50	August 28	1410	1079	−331
Alorco Cryolite	August 28	1442	1447	+ 5
Gesarol A-3	August 28	1313	1499	+186
None		1123	635	−488
Kryocide	August 17	1405	1060	−345
Kryocide	August 17, 28	1483	1541	+ 58
Kryocide	August 17, 28, September 7	1587	1608	+ 21
None		1006	564	−442
Kryocide	August 17	1405	1060	−345
Kryocide	August 28	1265	1342	+ 77
Kryocide	September 7	1100	1028	− 72
None		971	654	−317
L.S.D. 19:1	One date	198	198	
L.S.D. 19:1	Different dates	240	240	

[1] Between digging dates.

one treatment, *Kryocide*, on September 7 was too late to prevent a reduction in yield.

The time of digging under conditions of worm damage is of great importance to the farmer, as indicated by yields taken October 9. On untreated plots, losses ranged from about 300 to nearly 500 pounds per acre. Most of this was due to detachment of the nuts in the ground when dug. Records on October 9 also show the relative effectiveness of the treatments. They indicate no significant difference between the natural and synthetic cryolite products. A loss of 331 pounds occurred between digging dates on the plot treated with *Kryocide D-50*, indicating the lower effectiveness of this diluted cryolite product. Although there was a gain of 186 pounds per acre between digging dates on the plot dusted with DDT, this figure probably is not statistically significant. However, this substantiates the data on worm counts (Table 2) and indicates the possibility that DDT may be more effective than cryolite under critical conditions. The worm counts indicate that DDT was quicker acting and was effective over a longer period than cryolite.

Three applications of *Kryocide* did not significantly increase the yield over two applications. On the other hand, the yield from the plot given two treatments was only slightly greater than that from the plot dusted once on August 28, but was much greater than the yield from the plot

Table 2.—Worm counts on peanut plots dusted for the control of the velvetbean caterpillar. Plots dusted August 28 only.

TREATMENT	DAYS AFTER TREATMENT					
	0	2	4	8	15	29
	No. Worms per Unit[1]					
Kryocide	14.2	8.2	2.0	5.2	17.2	15.2
Kryocide D-50	13.0	13.0	8.5	14.2	42.0	12.0
Alorco Cryolite	14.7	10.2	7.2	5.2	19.2	10.2
Gesarol A-3	20.7	3.2	2.5	1.0	10.0	9.7
None	19.7	24.2	31.5	30.0	40.0	9.7

[1] Average of 4 units, each 2 linear feet of row.

given one dusting on August 17. It is evident that dusting with *Kryocide* on August 17 was too early to maintain worm control that season and that dusting on September 7 was too late to prevent worm damage.

The data show clearly that the week of August 28 was the critical period (Fig. 1). The worm population increased rapidly from August 28 to September 5 and remained high until the food supply was depleted.

THE RELATION OF YIELDS AND WORM COUNTS.—Mr. Schultz,[1] who did the statistical work for this paper, states, "It would be safe to say that the treatments affected the worm populations and the

[1] The author expresses his appreciation to E. F. Schultz, Jr., of this Station, for the analyses.

yields, and that the effect on the yields was inversely related to the number of worms found on the plants. Further, it can be said that practically all the differences in yields were due to the numbers of worms present."

The correlation between worm counts and yields harvested September 28 was not as close as that between worm counts and the yields of October 9, since losses increased as digging was delayed. The correlation coefficient for the former was −0.68 and −0.90 for the latter.

Regression lines were calculated for the yields taken October 9 (Fig. 2). It will be observed that the yield harvested declined more rapidly than the total yield (yield on vines plus yield lost in the ground), as the worm population increased. Hence, worm damage to peanuts is two-fold: a direct reduction in yield due to impaired plant production, and an increase in the nuts detached and left in the ground.

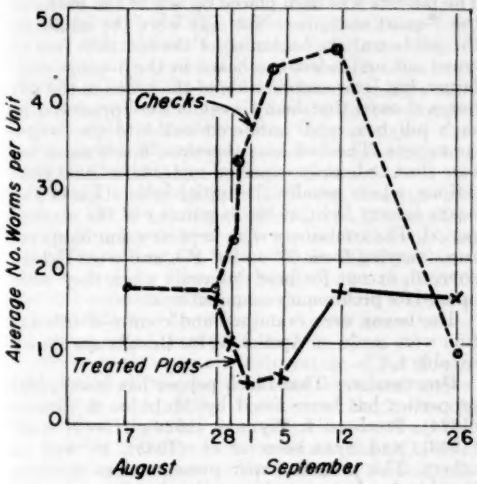


FIG. 1.—Average number of worms per 2-foot unit of row on three checks compared with average per unit on three plots dusted with cryolite August 28.

FIELD OBSERVATIONS.—Larvae of the velvetbean caterpillar are easy to kill. The large worms are for the most part top feeders, and are ravenous eaters. Hence, distribution and placement of the dust is not a mechanical problem. From large-scale dusting operations carried out on the Station with a 6-row power duster, it was evident that the drift from the duster did not give effective control. A heavy deposit directly to each row is required. In one field dusted by an airplane flying crosswise of the rows, the protected streaks of peanuts could be clearly distinguished. Worm damage increased as one proceeded from the center of the swath. Hence, if dusting is to be done by airplanes, the swaths will have to be relatively close together.

Migration of larvae from field to field is of no consequence, but they will move toward better food within an infested field.

SUMMARY.—Tests were made on the velvetbean caterpillar with DDT and cryolite dusts. A product containing about half the usual quantity of sodium fluoaluminate was not as effective as undiluted cryolite. Indications were that a 3 per cent DDT dust was perhaps more effective in controlling worms than undiluted cryolite. However, this was not manifested by yields to any appreciable extent. One timely application of cryolite gave excellent control.

The loss of nuts ranged from 200 to 1000 pounds per acre, depending on the degree of worm control and the date the peanuts were dug. Losses increased with worm populations and delay in digging.—5-1-46.

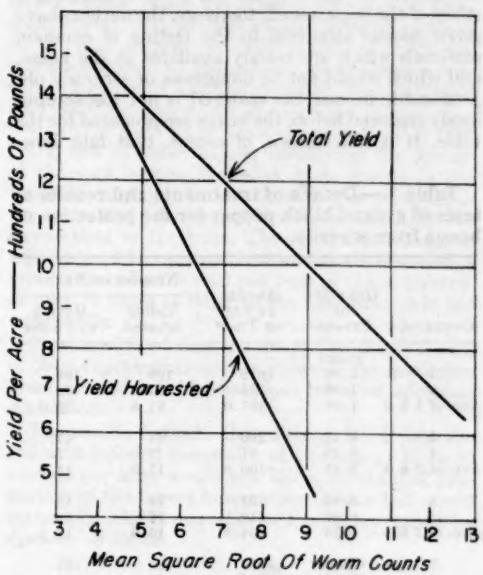


FIG. 2.—Regression lines showing the relationship of yield to worm counts.

SCIENTIFIC NOTES

Black Pepper to Control the Bean Weevil

F. H. LATHROP and L. G. KEIRSTEAD,
Maine Agricultural Experiment Station, Orono

The bean weevil, *Acanthoscelides obtectus*, is a destructive pest of stored beans. Where beans are stored in large quantities by commercial establishments, adequate control measures can be practiced for combating the insect. For the protection of small quantities of beans in the home or on the farm, however, no entirely satisfactory insecticidal treatment is available. The result is that, in the aggregate, large quantities of home-stored beans are destroyed by weevils, with considerable loss and much annoyance to the householders. In conducting a study of the bean weevil, therefore, the authors have given special attention to the testing of common materials which are readily available in the home, and which would not be dangerous or seriously objectionable in case the material is not too scrupulously removed before the beans are prepared for the table. It is well known, of course, that talc, lime, and other inert dusts, when mixed with beans, give effective protection against weevils. Such dusts seem objectionable, however, unless they are very thoroughly removed from the beans.

Table 1.—Details of treatments and results of tests of ground black pepper for the protection of beans from weevils.

Container	Quantity of Pepper[1]	Adults at End of Test[2]	Number of Beans[3]	
			Visibly infested	Having exit holes
	grams			
1	1.06	1699	109	106
2	1.06	515	54	52
Ave. of 1 & 2	1.06	1107.0	81.5	79.0
3	2.13	289	27	27
4	2.13	91	7	7
Ave. of 3 & 4	2.13	190.0	17.0	17.0
5	4.26	91	14	13
6	4.26	118	12	12
Ave. of 5 & 6	4.26	104.5	13.0	12.5
7	Check	4653	163	161
8	Check	5390	163	163
Ave. of 7 & 8	Check	5021.5	163.0	162.0
Percentage of reduction of infestation in treated beans compared with checks				
Minimum	1.06	63.5	33.1	34.2
Maximum	1.06	90.4	66.9	68.1
Average	1.06	78.0	50.0	51.2
Minimum	2.13	93.8	83.4	83.2
Maximum	2.13	98.3	95.7	95.7
Average	2.13	96.2	89.6	89.5
Minimum	4.26	97.5	91.4	91.9
Maximum	4.26	98.3	92.6	92.6
Average	4.26	97.9	92.0	92.3

[1] Table grade, ground, black pepper.
[2] Total number of adults in the 1-quart container.
[3] Counts were made of a representative sample of 200 beans from each container.

In an effort to discover a material which would meet home requirements, laboratory tests were made of bicarbonate of soda, table salt, and wheat flour; all with unsatisfactory results. Of the materials tested, black pepper only appeared to give much promise.

On December 21, 1945 a test of ordinary, table-grade, ground, black pepper was started at Orono, Maine. For the test, one pine (385 grams) of yellow-eye beans was placed in each of 8 cylindrical paper containers of 1-quart capacity, with tightly fitting covers. Black pepper, in the quantities specified in table 1, was placed in the boxes, and thoroughly shaken with the beans. To infest the beans in each container, a round paper pill box was filled with about 24 beans from a source heavily infested with weevils. Ten adult weevils were placed with the beans in each pill box. Four holes (5 mm. diameter) were punched at regular intervals through the side wall of the pill box to permit free egress of adults. The pill box was then placed on top of the beans in the 1-quart container. Not only were the adults in the pill box at the beginning of the test thus free to crawl out and infest the beans in the 1-quart container, but later examination of the beans in the pill boxes showed that many weevils were produced in each pill box, and wandered out into the larger containers. The test was therefore much more severe than ordinarily expected under household conditions, where usually the initial infestation of the beans is very light at the beginning of the storage period. The containers were kept at room temperature (varying from 65° to 80° F.), and were tightly covered, except for brief intervals when they were opened for preliminary examinations.

The beans were examined and counts of infestation were made on April 9, 1946. Results are shown in table 1.

DISCUSSION.—That black pepper has insecticidal properties has been noted by McIndoo & Sievers (1924), Freeborn & Wymore (1929), Harvill *et al.* (1943), and Synerholm *et al.* (1945), as well as others. The present paper presents data showing that black pepper may have value for the protection of home-stored beans from attacks of weevils. Although the data presented appear to indicate satisfactory control under conditions of laboratory tests, further study should be made to ascertain the performance of black pepper on a somewhat larger scale, and under conditions more closely simulating those met with in household and farm storage.—4-19-46.

LITERATURE CITED

Freeborn, Stanley B. and Floyd H. Wymore. 1929. Attempts to protect sweet corn from infestations of the corn ear worm, *Heliothis obsoleta* (Fabr.), JOUR. ECON. ENT. **22**: 666–71.

Harvill, Edward K., Albert Hartzell, and John M. Arthur. 1943. Toxicity of piperine solutions to houseflies. Contrib. Boyce Thompson Inst. **13**: 87–92.

McIndoo, N. E. and A. F. Sievers. 1924. Plants tested for or reported to possess insecticidal properties. U.S.D.A., Dept. Bul. **1201**.

Synerholm, Martin E., Albert Hartzell, and John M. Arthur. 1945. Derivatives of piperic acid and their to toxicities toward houseflies. Contrib. Boyce Thompson Inst. **13**: 433–42.

DDT and Hibernating Larvae of the European Corn Borer

D. D. QUESTEL, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The possibility of killing larvae of the European corn borer, *Pyrausta nubilalis* (Hbn.), by disking DDT into the soil along with infested cornstalks in which they are hibernating was suggested. Some laboratory experiments were therefore conducted to determine the mortality of hibernation-type borers caused by burying them in soil treated with DDT.

Two pounds of moist soil was placed in each of 10 half-gallon buckets, the lids of which were perforated for ventilation. To simulate the disking operation, a dust containing DDT was stirred into the soil to a depth of a little more than 1 inch in 4 of the buckets, at a rate equivalent to 200 pounds per acre. A dust containing 5 per cent of DDT micronized on clay was used in two buckets and a similar dust containing 20 per cent of DDT was used in the other two. In four other buckets the surface soil was treated with a solution containing approximately 5 per cent of DDT dissolved in deodorized kerosene. This solution was used at a rate equivalent to 200 pounds per acre in three buckets and at 400 pounds per acre in one bucket. To serve as a check the soil in the two remaining buckets was left untreated.

A hole 1 inch deep and 2 inches in diameter was made in the soil in the middle of each bucket. Ten hibernation-type larvae were placed therein and buried by refilling the hole with the DDT-soil mixture. In 2 of the 3 buckets treated with the DDT-kerosene solution at 200 pounds per acre the kerosene was allowed to evaporate for 24 hours before the larvae were buried in them.

After a week at an air temperature of 70° F. the contents of all the buckets were examined and a record was made of the condition of the larvae. It was evident that they had crawled around on the soil and had therefore been exposed to the DDT to a considerable extent, since the surface of the soil was covered with many fine silk threads spun by the larvae.

It was considered that the larvae in these tests were exposed to the action of the DDT to a greater extent than they would have been under field conditions. After a short period of movement, and considerably before the end of the 7-day period, the larvae had come to rest and had spun webbing in preparation for pupation. It is assumed that this action is similar to that which would have occurred in the field following disking in the spring, except that probably the activity was greater in the case of the laboratory material owing to the higher temperature. Where corn is disked in the fall the borers would be encased in portions of the corn plant where they would be protected from contact with the DDT until warm weather incites migration activity prior to pupation. In such cases it is thought that there would be no greater activity than occurred in these tests. Fumigation action by the DDT was considered a negligible factor.

The experiment was repeated twice, with fresh lots of larvae, under the same conditions and technique except that the soil was not kept so moist as in the first experiment. The condition of all the larvae subjected to the different treatments in the three experiments and the causes of death, so far as they could be determined, are shown in table 1.

In all the tests there was a strong indication that DDT was in some manner controlling the disease of the corn borers. Mortality from disease in the treated lots ranged from 1.25 to 2.5 per cent and in the untreated lots from 20 to 70 per cent of the larvae used in the tests. There was an average of 2.08 per cent larvae dead from disease in the treated lots compared with 38.3 per cent in the untreated, or over 18 times as much in the untreated as in the treated lots.

It is considered that the quantities of DDT used in these experiments were in excess of the maximum practical under field conditions from an economic standpoint.

The results indicate that disking DDT into the soil with infested cornstalks at the rate of 10 to 40 pounds per acre would not kill a substantial proportion of the borers hibernating therein but would materially inhibit mortality of the borers caused by disease.—5-23-46.

Table 1.—Mortality of European corn borers buried in soil treated with DDT and in untreated soil; 30 larvae in each test, 10 in each bucket.

TREATMENT	POUNDS OF DDT PER ACRE	Alive and unaffected	Dead from DDT or kerosene	Alive but affected by DDT or kerosene	Apparently killed by disease
DDT micronized on clay:					
5 per cent	10	28	1	0	1
		25	4	0	1
20 per cent	40	21	3	6	0
		21	4	4	1
DDT, 5 per cent, in deodorized kerosene:					
Larvae buried immediately[1]	10	6	5	18	1
	20	0	17	13	0
Larvae buried 24 hours after treatment[2]	10	27	0	3	0
		28	1	0	1
Check (no treatment)	—	20	0	0	10
		17	0	0	13

[1] Excess dead and moribund larvae indicate effects of kerosene.
[2] Effects of kerosene apparently mitigated.

DDT in Colloidal-Type Suspensions[1]

HOWARD A. JONES[2] and HELEN J. FLUNO, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

During the early part of the work on DDT at the Orlando, Fla., Laboratory of the Bureau of Entomology and Plant Quarantine, certain colloidal-type suspensions were developed (Jones *et al.* 1945), primarily for use as mosquito larvicides, but also for residual sprays and other purposes. The colloidal-type of suspension was not developed to the point of actual use by the armed forces because it did not appear to be so widely applicable for military use as did emulsions and other preparations. Since it may be useful for some insecticidal purposes, however, a few formulations of this type are described here.

At 1 or 2 per cent of DDT the suspensions were quite stable when *Nopco 1216* was used with either acetone or *Cellosolve*. It would thus be possible to prepare 2 per cent DDT suspensions of this type for spraying purposes.

In March 1943 colloidal or nearly colloidal suspensions of DDT were prepared by adding to water a solution of DDT and *Wetsit Concentrated* (alkylated aromatic sulfonate) in *Cellosolve* (ethylene glycol monethyl ether). Later, with concentrates comprising 10 per cent of DDT, 10 per cent of surface-active agent, and 80 per cent of *Cellosolve*, preliminary comparisons were made of the physical stability of aqueous suspensions using different surface-active agents. These comparisons were made at a concentration of 10 p.p.m. of DDT. Separation of DDT began immediately when no surface-active agent was used, in 24 hours with *Triton B-1956* (polyglyceride of a glyptal resin), in about 1 week

Table 1.—Approximate stability[1] of DDT suspensions prepared with various surface-active agents and water-miscible solvents. Composition of concentrates: DDT 20%, surface-active agent 20%, solvent 60%. Aqueous suspensions contained 0.5% of DDT.

Solvent	Surface-Active Agent: Triton B-1956	Wetset Concentrated	Nopco 1216	Triton X-100
Cellosolve[2]	Good	Very good	Very good	Very good
Acetone	Poor	Poor	Very good	Very good
Dioxane	Poor	Fair	Good	Very good
Cellosolve acetate (ethylene glycol monoethyl ether acetate)	Fair	Fair	Fair	Good
Carbitol acetate (diethylene glycol monoethyl ether acetate)	Fair	Fair	Fair	Fair
Butyl *Carbitol* (diethylene glycol monobutyl ether)	Good	Very good	Good	Poor

[1] Poor = immediate flocculation; fair = separation evident after 15 minutes to 1 hour, marked separation in 24 hours; good = separation evident after 15 minutes to 1 hour, slight separation in 24 hours; very good = no evident separation in 24 hours.
[2] Concentrates made with *Cellosolve* contained 10% of DDT, 10% of surface-active agent, and 80% of *Cellosolve*. *Vatsol OT* used with *Cellosolve* gave a DDT suspension with approximate stability rated as good.

Table 2.—Approximate stability[1] of DDT suspensions at several DDT concentrations.

Composition of Concentrate (Figures in Per Cent)				Stability of Suspension of Indicated DDT Content		
DDT	Surface-Active Agent		Solvent	1 Per Cent	2 Per Cent	5 Per Cent
15	*Triton X-100* 15		Acetone 70	Fair	Fair	Poor
10	*Triton X-100* 10		*Cellosolve* 80	Fair	Fair	Poor
15	*Nopco 1216* 15		Acetone 70	Very good	Very good	Poor
10	*Nopco 1216* 10		*Cellosolve* 80	Very good	Very good	Poor

[1] See footnote 1, table 1.

These suspensions were more stable at low than at high DDT concentrations. To determine the practical upper limit of DDT concentration in some of these suspensions, comparisons were made at 1, 2, or 5 per cent of DDT with concentrates containing *Nopco 1216* and *Triton X-100* in acetone or *Cellosolve*. The results of these tests are shown in table 2. At 5 per cent, separation of DDT occurred immediately with *Vatsol OT* (dioctyl sodium sulfosuccinate), and in 10 days to 2 weeks with *Wetsit Concentrated*. There was no evidence of separation after several weeks with *Nopco 1216* (sulfonated sperm oil) and *Triton X-100* (polyethylene glycol alkyl aryl ether).

Several water-miscible solvents were then tested with the same surface-active agents. Concentrates were added to water to give suspensions containing 0.5 per cent of DDT. Observations of physical stability are shown in table 1. At this DDT concentration *Cellosolve* appeared to give stable suspensions with the several surface active agents used. Acetone, dioxane, and butyl *Garbitol* gave stable suspensions in some cases.

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.
[2] Now with the Unit of Entomological Research, Dodge & Olcott, Inc., Baltimore, Md.

Those colloidal-type suspensions, especially the *Nopco 1216-Cellosolve* preparation, were tested rather extensively for use as mosquito larvicides and were found to be highly effective. However, at the concentrations necessary to obtain long-lasting results, they did kill fish and other aquatic life. They appeared to be particularly applicable to the control of mosquito larvae in abandoned cisterns, fire barrels, and other static bodies of water where other aquatic life was not important and effectiveness for long periods of time was desired. This type of suspension was also effective when tested as a residual spray against adult mosquitoes and flies and may have some application for this purpose. Although further work would be necessary to develop completely satisfactory formulas for the preparation of colloidal-type suspensions of DDT, the observations just given point to the possibilities along this line.—5-13-46.

LITERATURE CITED

Jones, H. A., H. J. Fluno, and A. B. Hendrick. 1945. DDT insecticidal preparations. JOUR. ECON. ENT. 38: 207–10.

Effect of DDT Residual Deposits on Scorpions

GEORGE A. THOMPSON, *S. A. Sanitarian (R)*

During 1945 applications of 5 per cent DDT residual type spray, in kerosene were made at Fort Simonds, Jamaica, B.W.I. to aid in malaria control. Following the first applications made in natives' houses reports were received that the spray was killing scorpions, probably *Centrurus margaritatus* (Gervais), as this is the common species on the Island. Specimens have been sent to the U. S. National Museum for confirmation of identification. Little attention was paid to the reports as it was supposed that the liquid spray had contacted the scorpions while they were hiding about the treated houses. The reports, however, continued beyond a reasonable length of time for the individuals that had been sprayed to have either died or recovered. Later a small building on the Post, in use as a "quick lunch" stand was treated with DDT residual type spray. Each morning for between 2 and 3 weeks thereafter, one or two dead or moribund scorpions were found on the floor of the lunch stand. It appeared, therefore, that the DDT residue was killing the scorpions since there were not many places in the lunch stand where they could have hidden and been protected from the spray during application.

In an experiment to determine the effect of DDT on scorpions, eight specimens were caught and brought in contact with a freshly sprayed surface by allowing them to remain on the surface several minutes and then confining them to clean cages. The individuals ranged in size from about 2 inches total length to slightly over 4 inches. All died within 12 hours of their contact with the residue.

During the first 2 weeks of August 1945 several quarters on the Post were treated with DDT 5 per cent residual type spray to reduce infestations of several species of insects. The quarters were closed for about a month before being opened for use by military personnel. During the third week in September the last of the quarters were opened 10 dead scorpions were found on the floor, all within 6 inches to a foot of the walls. It is not believed that this number of scorpions were sprayed at the time the house was treated; however, they may have come in contact with the spray before it dried. Scorpions were found in some of the treated quarters and not in others. This may have no significance since many houses are not infested.

Mr. W. H. W. Komp, Sanitary Engineer Director, U.S.P.H.S. has informed the writer that he observed similar effects of DDT on scorpions while working in British Guiana.—5-18-46.

Effects of DDT on Certain Microbiological Processes in the Soil

J. K. WILSON and R. S. CHOUDHRI,
Cornell University, Ithaca, New York

Although DDT has been known for many years it has not been used extensively as an insecticide until recently. Apparently the quantity of this substance required to control certain insects is not large, usually less than 100 pounds an acre, yet this quantity might be sufficient to interfere with certain microbial processes. This preliminary note, therefore, contains data concerning the effect of this substance on certain organisms normally found in the soil. Such an effect was ascertained by studying the processes carried on by organisms in the soil or by testing the effect of the material on pure cultures of certain organisms growing in test tubes.

MATERIAL.—The material used in these tests consisted of 75 per cent talc and 25 per cent dichlorodiphenyl-trichloroethane. It was obtained from the du Pont de Nemours Company and for convenience is referred to as DDT.

RESULTS.—*Effect of DDT on the soluble salts in the soil:* In order to test the effect of DDT on the soluble salts in the soil solution Dunkirk silty clay loam was used. To it was added one per cent of the agent. After thorough mixing the soil was held in tumblers at room temperature. The moisture was adjusted so that the total weight of 100 grams of dry soil was 125 grams. This moisture was maintained by frequent weighing and by the addition of water. After 8 and 16 days the soluble salts were determined. This was accomplished by screening the soil through a one millimeter sieve, weighing a certain amount, extracting with two times its weight of water, and obtaining the electrical resistance of the supernatant liquid. The pounds an acre were calculated as sodium chloride by using a standard curve. A summary of the results follows:

	SOLUBLE SALTS POUNDS PER ACRE			
Control	12 days	10	24 days	13
1% DDT		12		12

Effect of DDT on the accumulation of nitrate in soil: Dunkirk silty clay loam was obtained from the experimental plots, spread on paper in the laboratory and when sufficiently dry screened to remove stones and to insure a fairly uniform sample. After determining the moisture DDT was added to equal 0.5 per cent of the dry weight of the soil. The moisture was then adjusted so that 100 grams weighed 125. To this moisture was added enough nitrogen as ammonia so that if it were all oxidized it would give about 200 p.p.m. of nitrate. Controls were provided. The soil was held in tumblers for 21 days. The con-

tainers designated as controls were kept in one incubator and the ones holding the soil treated with DDT in another. The nitrate in the soil was determined by the phenoldisulfonic acid method. The findings are summarized.

	NITRATE IN SOIL SOLUTION
Control	45 p.p.m.
Control	48
Soil with 0.5 per cent DDT	48
Soil with 0.5 per cent DDT	48

Effect of DDT on the production of ammonia from organic materials: To make this test certain quantities of organic matter and DDT were mixed with the Dunkirk silty clay loam and the moisture adjusted to have 25 ml. of water with each 100 grams of the dry soil. The same was provided without the DDT. These cultures were then held in tumblers at room temperature for 7 days, at which time the ammonia was extracted with normal hydrochloric acid. Aliquots were made alkaline with sodium hydroxide and the ammonia distilled into standard sulfuric acid. From the findings the amount of ammonia produced was calculated. The results follow.

	AMMONIA IN SOLUTION
Peptone 0.5 per cent	42.0 p.p.m.
Peptone with 0.5 per cent DDT	37.6
Casein 0.5 per cent	43.0
Casein with 0.5 per cent DDT	43.4
Dried blood 0.5 per cent	7.0
Dried blood with 0.5 per cent DDT	8.8

Effect of DDT on the population of organisms by counting colonies on agar in petri dishes: The soil for this test was a part of that used in the previous tests. Enough of the partly-dried soil was taken to equal 100 grams, to which was added 0.5 gram of DDT. After thorough mixing the moisture was adjusted so that the total weight was 125 grams. The soil with a similar quantity of moisture was held as control. Determinations of the population were made at the end of 8 and 16 days. The medium used for planting is commonly referred to as soil extract-sucrose-agar. A summary of the counts is presented.

	NUMBER OF ORGANISMS IN MILLIONS IN A GRAM	
	8 days	16 days
Control	3.30	4.90
With 0.5 per cent DDT	2.91	4.28

Effect of DDT on the nodulation of legumes: About 1200 grams of Dunkirk fine sandy loam was used in each container. To this soil DDT was added. The quantities applied were 2, 1.5, 0.5, 0.25, 0.1, 0.05 and 0.0 per cent of the dry weight of the soil. These quantities were intimately mixed with the soil and the moisture adjusted to 23 per cent. The bacteria suitable for each species were dispersed in the water before it was added to the soil. This moisture was maintained by weighing each day and by adding distilled water. Alfalfa, red clover, soybean and vetch were grown for 35 days, during December and January. The daylight was supplemented by light from incandescent bulbs. As far as could be ascertained, adequate nodulation was present on the roots of all species irrespective of the presence of DDT.

Effect of DDT on the growth of pure cultures: (A) Legume Bacteria. Since the four species of legumes that were grown on the soil in the presence of heavy applications of DDT developed nodules freely it seemed appropriate to test the effect of this material on the growth of certain strains of the legume bacteria growing on agar slopes in test tubes. Thus, a freshly prepared medium suitable for the legume bacteria was prepared. By means of a flamed wire loop some of the DDT was spread on the surface of the agar. Subsequently the legume bacteria were mixed with the material on the slope. Isolates from the following legumes were used. *Alysicarpus vaginalis, Anthyllis vulneraria, Derris* (sp), *Dorycnium herbaceum, Heylandia latibrosa, Lebeckia simsiana, Leucaena glauca, Medicago sativa, Parryella filifolia, Schrankia uncinata, Trifolium repens, Virgilia capensis.* An examination after ten days showed copious growth of the bacteria in all cases.

(B) *Certain other organisms:* Certain other organisms were grown on the same medium as was used to grow the legume bacteria and the conditions were the same. The organisms included *Aspergillus niger, A. oryzae, Pen. italicum, Pen. requeforti, Pen. expansum, Pen. camemberti* and six other unidentified fungi. Also the alga, *Chlorella*, and 5 other unidentified species; 10 species of bacteria, and three species of actinomycetes were cultured in the presence of DDT. There appeared to be no injurious effect of DDT on the well being of any of these organisms.

DISCUSSION AND CONCLUSION.—The quantity of DDT mixed with soil or spread on the surface of an agar medium in test tubes was much in excess of that which will ever be applied for the control of insects yet there was no evidence that this material was injurious to microorganisms. Amonification, the accumulation of nitrate, and the normal concentration of salts in the soil did not seem to be seriously modified. Since no effect was noted from its application additional work with DDT seemed useless.—4-29-46.

Gross Infestations of the Domestic Rat with Ectoparasites

NEAL M. RANDOLPH and R. B. EADS, *Texas State Department of Health, Austin*

It has been noted that most literature on fleas list the sticktight flea, *Echidnophaga gallinacea*, as being commonly found on domestic rats, but in small numbers. Ewing & Fox (1943) state "Rats, as hosts to the pest, play an important part in its distribution, although the fleas are not very abundant on these rodents." It is believed that this idea has arisen because most domestic rat trapping has been done in urban areas where small numbers of chickens, the normal host of this flea, are found.

A large number of rats have been taken from both rural and urban areas in connection with a murine typhus research program being conducted by the Texas State Department of Health, in cooperation with the United States Public Health Service, in Lavaca County, Texas. Only a few scattered *Echidnophaga gallinacea* have been taken from the rats trapped in the three urban areas, Hallettsville, Shiner, and Moulton, in Lavaca County. However, this has not been true in the rural areas. Domestic rats trapped in buildings close to chicken houses frequently have shown large numbers of these fleas.

One rat, *Rattus rattus alexandrinus*, trapped alive, March 27, 1946, from a farm home near Hallettsville, Texas, possessed an infestation of *Echidnophaga gallinacea* and *Polyplax spinulosa* that is thought of sufficient interest to be reported. From the single rat 335 *E. gallinacea*, 1200 adult and late instar nymphs of *P. spinulosa* (it was estimated that as many more early instar nymphs were not counted) and 3 mites, *Laelaps hawaiiensis*, were taken. Two rats of this same species trapped alive on another farm also near Hallettsville, Texas, had large infestations of *E. gallinacea*. One of these rats trapped April 3, 1946, had 330 *E. gallinacea*, 22 *Leptosylla segnis*, and 17 *P. spinulosa;* and the other rat was infested with 100 *E. gallinacea* and three *P. spinulosa*.

Approximately 50 per cent of the fleas, mainly females, were firmly attached to the rats about the nose and head, requiring considerable pressure on the forceps to release them. Some of the fleas were still attached 12 hours after the host had been killed. The remaining 50 per cent were running free over the host, or readily detached themselves when disturbed.

The *Polyplax spinulosa* also were found in large numbers about the head and shoulders, although the majority of the eggs were glued to the long hairs on the back near the tail. These lice showed very little inclination to leave the dead host. It is doubtful if these slow moving insects survive the death of a host by transferring to another.

Both *Echidnophaga gallinacea* and *Polyplax spinulosa* are of interest in murine typhus transmission due to the large numbers found on rats. Both insects have been found naturally infected with the typhus Rickettsia by this laboratory.—4-14-46.

LITERATURE CITED

Ewing, H. E., and I. Fox. 1943. "The Fleas of North America." U.S.D.A. Misc. Publ. 600.

Benzene Hexachloride for Animal Parasites

RAYMOND ROBERTS, *Texas Agricultural Experiment Station, Weslaco*

Crude benzene hexachloride (the new insecticide from England), is quite efficient in the control of dog fleas, *Ctenocephalides canis*, and the lone star tick *Amblyomma americanum*. A dog so heavily infested with fleas that they could be seen crawling through the hair and coming to the surface, was treated with about two or three teaspoonfuls of benzene hexachloride, 5 per cent strength, and this was rubbed into the hair. The dog is a medium sized, short-haired animal. Following the application, the dog laid on a light colored linoleum for about an hour. At the end of this time 54 paralyzed fleas were collected from the floor where the dog had rested, and in the path by which he left. Four hours later the dog was examined. No fleas were found on it.

Fleas were taken from the dog 3 and 4 days later, even though there was still an odor of benzene hexachloride on the dog. This would indicate little or no residual effect of the insecticide on warm blooded animals.

A second dog was similarly treated and held over a sheet. Nearly a teaspoolful of fleas were removed from the sheet. While these fleas were only paralyzed, which caused them to fall to the floor, none recovered. Slight reflexes could be detected in the legs 4 hours after the treatment. Neither dog showed any ill effects of the treatment.

Four ticks, *Amblyomma americanum*, located near the ears of one dog, a pair on each side, were treated with a pinch of dust. Three unengorged specimens were paralyzed within 30 minutes. The fourth, a partially engorged female, continued active for about 2 hours. Action of crude benzene hexachloride against the tick is relatively slow as all four ticks retained some reflexes for 12 hours after treatment and removal from the dogs. These ticks, as well as another group of four, and one large scorpion, were killed by the benzene hexachloride with this relatively heavy application. Complete cessation of reflex action was not noted. From 12 to 16 hours will be required for killing but the parasites quit feeding almost immediately.

These limited observations indicate that benzene hexachloride is a promising insecticide for the control of animal parasites and should receive intensive study.—5-1-46.

Comparative Toxicity to Insects of Benzene Hexachloride and DDT[1]

G. T. BOTTGER and CLEMENCE LEVIN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Benzene hexachloride and DDT have been tested in the laboratory against 10 species of insects in order to compare the toxicity of these two insecticides. The insects employed in the tests represent the orders of Coleoptera, Hemiptera, and Lepidoptera and include the following species:

Alder flea beetle	*Altica bimarginata* (Say)
Armyworm	*Cirphis unipuncta* (Haw.)
Celery leaf tier	*Phlyctaenia rubigalis* (Guen.)
Corn earworm	*Heliothis armigera* (Hbn.)
Imported cabbage worm	*Pieris rapae* (L.)
Large milkweed bug	*Oncopeltus fasciatus* (Dall.)
Melon worm	*Diaphania hyalinata* (L.)
Southern armyworm	*Prodenia eridania* (Cram.)
Southern beet webworm	*Pachyzancla bipunctalis* (F.)
Variegated cutworm	*Peridroma margaritosa* (Haw.)

The large milkweed bug, melon worm, southern armyworm, and southern beet webworm were reared and tested in the laboratory at Sanford, Fla. All other species were tested at Anaheim, Calif. The larvae of the corn earworm, imported cabbage worm, and alder flea beetle were collected in the field, while those of the armyworm, celery leaf tier, and variegated cutworm were reared in the laboratory.

Phytotoxicity, or foliage-injury, tests were made by treating foliage of 11 varieties of plants growing in an outdoor garden in Florida. Benzene hexachloride was tested against beets, collard, peas, pumpkin, radishes, and Swiss chard, while DDT was applied to

[1] The pure gamma isomer of benzene hexachloride used in these tests was supplied through Alexander King of the British Central Scientific Office, and the technical DDT was furnished by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine.

Table 1.—Comparative toxicity of benzene hexachloride and DDT when applied to foliage as dusts to control 10 species of insects.

Insect[1]	Feeding		Concentration	Deposit		Mortality in 3 Days	
	Benzene hexachloride	DDT		Benzene hexachloride	DDT	Benzene hexachloride	DDT
			Per Cent	*Micrograms per sq. cm.*		*Per Cent*	*Per Cent*
Celery leaf tier	Much	Slight	0.5	95	95	0	79
Southern armyworm	Slight	Slight	0.5	110	110	96	17
Large milkweed bug*	—	—	1.0	125	125	75	17
Melon worm	Moderate	Much	0.1	115	115	100	54
Southern beet webworm	Moderate	Much	0.1	95	95	100	67
Alder flea beetle	None	None	2.0	140	255	100	75
Imported cabbage worm	Moderate	Much	0.1	110	125	96	75
Armyworm	Moderate	Moderate	0.5	85	115	88	71
Corn earworm**	Much	Much	0.5	140	140	42	33
Variegated cutworm	Moderate	Moderate	0.5	95	85	83	92

[1] Fourth-instar larvae were used, except *nymphs and **fifth instars.

beans, collard, corn, potatoes, pumpkin, squash, and tomatoes.

MATERIALS.—The pure gamma isomer of benzene hexachloride and technical DDT were used in the tests reported. These toxicants were diluted in Fuller's earth to strengths of 5 to 1 per cent for spray tests and 2 to 0.5 per cent for dusts. This diluted material was employed at the rate of 2 pounds per 100 gallons of water in making sprays and of 255 to 85 micrograms per square centimeter for dusts. Saponin at the rate of 2 ounces per 100 gallons of water was added to the spray to insure proper wetting.

METHODS.—The dust and spray tests were made by confining sections of treated leaf or host material with fourth- or fifth-instar larvae. Contact tests against the milkweed bug were made by dusting fourth-instar nymphs of this insect and then confining them with untreated food in glass crystallizing dishes. In general the methods and equipment were similar to those described by Swingle *et al.* (1941). A 3-day test period was allowed for all insect-toxicity tests, but dead insects were removed from the petri dishes on each day following the treatments. The spray treatments were applied by means of an atomizer which releaesd the material under pressure of about 10 pounds per square inch. For testing phytotoxicity, 5 per cent DDT and benzene hexachloride were applied with a hand sprayer to green foliage at the rate of 8 pounds per 100 gallons of water. Both sides of the leaves were treated twice. The treatments were made 7 or 8 days apart and records made 14 or 15 days after the first treatment. The treated foliage was protected from rain during the test period.

RESULTS OF DUST TESTS.—Dust treatments of benzene hexachloride gave greater mortalities than similar treatments of DDT when tested against the southern armyworm, large milkweed bug, melon worm, southern beet webworm, alder flea beetle, imported cabbage worm, armyworm, and corn earworm. Against the celery leaf tier, however, a dust treatment of DDT resulted in 79 per cent mortality of fourth-instar larvae, while the same deposit of benzene hexachloride had no apparent lethal effect. Comparatively low deposits of both insecticides were effective against the variegated cutworm, with slightly superior performance of DDT against this insect also. Data from dust tests are presented in table 1.

RESULTS OF SPRAY TESTS.—Spray treatments of benzene hexachloride were more effective than spray treatments of DDT employed at the same concentration when tested against the imported cabbage worm, southern armyworm, and southern beet webworm. The mortality of melon worm larvae from

Table 2.—Comparative toxicity of benzene hexachloride and DDT when applied to foliage as sprays to control four species of insects.

Insect[1]	Feeding		Concentration	Mortality in 3 Days	
	Benzene hexachloride	DDT		Benzene hexachloride	DDT
			Per Cent	*Per Cent*	*Per Cent*
Imported cabbage worm	Moderate	Much	0.002	96	13
Southern armyworm	Much	Much	0.01	58	29
Southern beet webworm	Much	Much	0.002	67	54
Melon worm	Much	Much	0.002	79	96

[1] Fourth-instar larvae were used.

the DDT spray treatment was 17 per cent higher than from a similar treatment of benzene hexachloride. Data from spray tests appear in table 2.

RESULTS OF PHYTOTOXICITY TESTS.—The DDT spray caused no apparent injury to green foliage of bean, collard, corn, potato, pumpkin, squash, and tomato plants. Similar applications of benzene hexachloride made on foliage of beets, collard, peas, radishes, and Swiss chard resulted in no apparent injury. A very slight sclerosis developed on treated pumpkin leaves, but subsequent development of pumpkin plants did not appear to be affected adversely.—5-20-46.

LITERATURE CITED

Swingle, M. C., A. M. Phillips, and J. B. Gahan. 1941. Laboratory testing of natural and synthetic organic substances as insecticides. JOUR. ECON. ENT. 34(1): 95–9.

DDT Used in Control of Latrine Flies

DEANE P. FURMAN[1]

One of the most vexing problems confronting sanitarians in tropical military operations is the prevention of fly breeding in human excreta; even well constructed latrines require constant maintenance to minimize the fly problem.

While stationed at an army base in New Guinea, the writer had an opportunity to test the insecticidal properties of DDT in the field against larvae and adults of the latrine fly, *Chrysomyia megacephala* (F.). This fly was a common pest at this base as well as at others in the Southwestern Pacific area, breeding commonly in latrines and appearing as adults around mess halls and native markets.

A series of five well established pit latrines was selected for the experiment. All were located within 300 yards of a central point and were separated by approximately a quarter mile from any other latrines. The pits were supplied with the standard eight-seat quartermaster latrine boxes which upon inspection seemed to be reasonably fly proof. They were breeding flies in moderate to large numbers, however, presumably due to the fact that the seats were not of the self-closing type and were occasionally left open. Prior to the experiment the latrines were burned out twice a week with waste paper and diesel oil or kerosene as a fly control method. This treatment was discontinued on all but one latrine which was used as a control.

The relative numbers of flies emerging from each latrine both before and after treatment were determined by attaching a permanent fly trap over one open seat of each box. Flies were collected from these traps at 24-hour intervals. For the three-day period prior to treatment the average numbers of flies trapped per day were as follows: Latrine No. 1—1270, No. 2—1100, No. 3—653, No. 4—215, No. 5—212. The selection of No. 3 as the control was made in view of its intermediate position in fly yield.

A 5 per cent DDT in kerosene spray was applied to latrines 1, 2, 4, and 5 by means of a 2-quart decontamination sprayer (Chemical Warfare Service), which gave a coarse droplet spray. The initial spray was applied at the rate of one quart per 250 square feet of wall space. The interior of the pit and contents, interior and exterior of the latrine box, the inside walls of the canvas latrine screen, and the ground inside the screen boundary were sprayed. Thereafter for a period of 2 weeks the contents of each pit was sprayed daily with 1 pint of the 5 per cent spray. The daily sprays seemed desirable for larval control since the latrines were in constant use and fresh media for fly breeding was available daily.

From the accompanying table it is readily apparent that the number of flies emerging from the treated latrines and surviving was markedly less than from the control latrine. However, since the control pit was burned out approximately twice weekly the number of flies obtained on given days varied greatly. Therefore a better picture of the actual control obtained may be seen in the accompanying graph, where the average of 16 daily collections from the control latrine is used as the basis for comparison. The fly control obtained for the fourteen day period of daily treatment ranged from 91.4 to 99.94 per cent.

DDT had a definitely delayed effect in killing the adult flies. This phenomenon is well demonstrated by comparing the total number of flies trapped daily with the number remaining alive at the end of twenty-four hours.

It is obvious that the number of flies alive in the traps at the time of daily collection included an indefinite number which had only recently been exposed and trapped, and which would soon have died from effects of the DDT. Therefore the control figures given above should be considered as slightly less than that actually obtained.

Since there was some question as to the possibility that flies coming into contact with DDT in the latrine might deposit enough of the material in the trap to affect unexposed flies, one of the traps from a test latrine was used for a day at the control site. No appreciable mortality was noted in flies caught in this trap in a 24-hour period. It will be noted in the table that natural mortality in flies caught at the untreated station was negligible.

The effectiveness of DDT as a larvicide seems to have been irregular. Using total numbers of flies trapped per day as the criterion, the effectiveness varied from 45 to 96.3 per cent during the 14 day period of daily treatment. However some of this

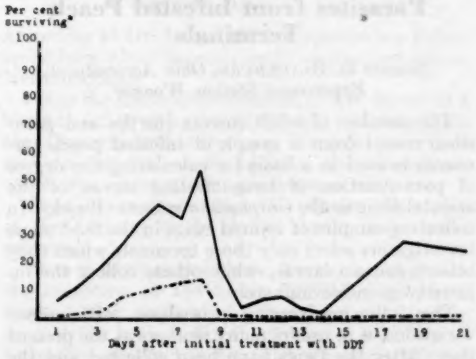


FIG. 1.—Flies trapped from DDT treated latrines.
Broken line shows average live catch from four treated latrines.
Solid line shows average total catch from four treated latrines.

[1] Major, Sanitary Corps, U.S.A.; At present Entomologist with the U. S. Public Health Service.

* 100 per cent equals 1606, the average of 10 daily fly catches from the control latrine.

Table 1.—Summary of flies captured in traps.

Days After Treatment	Latrine No. 1		Latrine No. 2		Latrine No. 4		Latrine No. 5		Control (Untreated)	
	Dead[1]	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
0–1	323	0	140	33	0	0	0	0	0	800
1–2	95	25	495	50	45	6	30	15	0	530
2–3	195	15	825	105	35	30	5	2	1	895
3–4	190	25	635	210	275	130	60	100	0	1265
4–5	425	75	675	300	525	220	5	5	0	930
5–6	270	75	1095	400	420	250	135	20	0	1105
6–7	310	50	1395	400	115	50	20	25	0	840
7–8	745	150	2205	400	44	1	0	2	1	1605
8–9	465	40	630	40	39	1	50	0	0	1525
9–10	112	3	75	5	53	2	57	0	0	2085
10–11	45	5	285	5	80	0	43	2	3	4935
11–12	197	3	295	5	3	2	5	0	0	2660
12–13	85	3	94	2	84	1	12	3	0	2832
13–14	104	1	67	0	15	0	24	1	1	2660
17–18	1230	50	385	40	8	10	50	5	3	670
20–21	1105	100	350	10	51	5	21	4	0	265
Total	5896	620	9646	2005	1792	708	517	184	11	25,692
Aver.	368	39	603	125	112	44	32	12	1	1606

[1] Traps were emptied every 24 hours at which time flies were separated into the dead and live categories.

apparent control of larvae was undoubtedly control of newly emerged adults which died in the pit after contacting DDT.

Following cessation of pit spraying on the 14th day the numbers of flies emerging from the pit increased markedly; this was not accompanied by a corresponding increase in numbers of flies surviving however, since on the 21st day the average number surviving from the test latrines was only 1.8 per cent of the 16 day average number emerging and surviving from the control latrine. This indicates that a daily spraying of the pit might be unnecessary as a practical control measure following an adequate initial spray treatment.—5-23-46.

Rearing Oriental Fruit Moths and Parasites from Infested Peach Terminals

NORRIS D. BLACKBURN, *Ohio Agricultural Experiment Station, Wooster*

The number of adult insects (moths and parasites) reared from a sample of infested peach terminals is used as a basis for calculating the degree of parasitization of twig-infesting larvae of the oriental fruit moth, *Grapholitha molesta* (Busck). In collecting samples of injured twigs in the field, some investigators select only those terminals which they believe contain larvae, while others collect the injured twigs indiscriminately.

The following rearing procedure, with minor variations, is in use by many workers at the present time. After the twigs have been collected and the foliage removed, the bare twigs are placed in a quart jar or other glass container with several green apples as supplementary food material. Frequently the terminals and apples are wrapped in paper toweling before they are placed in the container. Strips of corrugated paper are installed inside near the top of the jar which is covered with a section of fine-mesh cheesecloth held in place by a rubber band or a string.

Adequate provisions cannot be made easily in a glass container to eliminate excess humidity which develops as a result of evaporation of moisture from the green terminals. As a consequence, it is a common occurrence for mold and decay organisms to attack the twigs within a few days. Frequently, emerging insects become entangled in the moist debris and thus may be overlooked when periodic examinations are made for recording emergence. This difficulty may be overcome to a certain extent if the corrugations which contain the cocoons are transferred to a separate container.

The foregoing method is not entirely satisfactory, as some larvae are lost in the accumulated moisture while still others construct their cocoons in twigs and often die or are unable to emerge in the decaying material. This is particularly true in the case of fruit moth larvae parasitized by the ichneumonid, *Inareolata obliterata* (Cress.). Larvae thus parasitized frequently construct their cocoons in moist locations, such as burrows in injured twigs, or even in the interior of ripe peaches.

Many of the objectionable features associated with the rearing methods described above were eliminated by the following procedures which were developed and used by the writer during the 1945 season. Each individual sample of infested terminals (usually not exceeding 125) was wrapped in paper toweling in the field, moistened, and placed in a covered cylindrical, pasteboard ice cream container (quart size) with one or two small green apples. Strips of corrugations were placed inside the container near the top. If the paper toweling surrounding the twigs was liberally moistened at daily intervals for 5 or 6 days, the terminals remained in excellent condition in the closed container, quite suitable for larval feeding. Many of the terminals were almost entirely consumed under such conditions. Occasionally it was necessary to remove a sample

and separate the twigs which had become massed too tightly together.

At the end of 8 or 10 days, each sample, together with the towel wrapper and corrugations, was divided into two or more parts, depending upon the size, and transferred to glass containers where emergence records could be taken more easily. If the terminals were too moist at that time, they were left in the cardboard container for a longer period. When samples were not moistened for a few days prior to transference, they usually remained relatively free from mold throughout the entire emergence period, and insects that were overlooked in routine examinations were recovered readily from the dry debris when the rearing units were dismantled. When cardboard containers were used, it was found that the lid should not be removed by the usual twisting motion, otherwise larvae which constructed cocoons at the top would be injured.

The comparative efficiency of the two rearing methods, based on the relationship between infested terminals and emerging insects, is shown in the following table for the past three seasons. In general, all samples were collected by the same individuals, and all consisted of terminals believed (external evidence) to contain larvae at the time of collection. The seasons of 1943 and 1945 were similar with respect to optimum conditions for twig-larval collecting.

Table 1.—Relative efficiency of two different methods of rearing adult fruit moths and parasites from peach terminals damaged by and presumed to contain oriental fruit moth larvae.

Season	Total Terminals Collected	Rearing Technique Used	Total Insects Reared	Per Cent Productive Terminals
1943	7659	Glass	4655	60.8
1944	6647	Glass	3437	51.7
1945	8329	Cardboard-glass	6436	77.3

It will be observed that when the conventional technique of rearing was employed in 1943 and 1944, an average of 43.4 per cent of the total terminals collected for the two seasons failed to produce either moths or parasites. When the improved technique was used in 1945, only 22.7 per cent of the collected twigs was unproductive.—5-7-46.

The Abundance and Control of Flies on a College Campus

F. R. SHAW and A. I. BOURNE,
Massachusetts State College, Amherst

In connection with a program to reduce the fly nuisance on the campus of Massachusetts State College, a considerable amount of information was obtained. Some of the data would appear to be of sufficient interest to record.

The program was set up rather late in the season. Breeding was already occurring. Since this was the first time that fly control was to be attempted here, in a systematic way, it was felt necessary to study both the abundance and kinds of flies present, in order to determine the source of the infestation.

Through the cooperation of the Service Department, twelve fly traps were made. These were set up in areas where flies were likely to occur. A variety of materials was included as attractants. Among these were fish heads, chicken wastes, stale beer, manure, and a fermented bait prepared from molasses, corn meal and yeast. The latter was finally selected as the best type of bait from the standpoint of ease of handling, attractiveness to flies, and lack of objectionable odor. It was found that the addition of a few drops of bromoform added to the attractiveness of the bait.

The traps were visited twice a week, the old bait removed, and new bait supplied. The flies were removed from the trap once a week. In order to collect flies, a piece of canvas was placed around and over the trap. Then a small amount of calcium cyanide was placed on a paper which was inserted under the trap. Within a few minutes the flies were killed and then were shaken from the trap on to a paper. The amount of flies was determined by means of a pint measure. A sample from each trap was taken to the laboratory.

At the laboratory a random sample of 25 cc. of dead flies was obtained. It is realized that this technique may involve some error, but care was taken to try to select the random sample in the same manner each time, and to avoid any packing of the flies.

Specimens of flies were sent to the Division of Insect Identification, U. S. Bureau of Entomology and Plant Quarantine. Dr. M. T. James identified the material sent as follows:

Anthomyiidae
- *Fannia* sp.
- *Paregle cinerella* (Fall.)
- *Ophyra leucostoma* (Wd.)

Calliphoridae
- *Cynomyopsis cadaverina* (R.D.)
- *Lucilia illustris* Mg.

Piophilidae
- *Piophila* sp.

Sarcophagidae
- *Sarcophaga* sp.
- *S. bullata*
- *S. melanura* Mg.

According to Dr. James, the last species is a Palaearctic form which has previously been recorded from Newfoundland.

Using the material determined by Dr. James as a basis, together with additional named material from the Departmental collection, the more prevalent flies were determined. In addition, there were some which were grouped as miscellaneous.

The following data show the relative abundance of the different kinds of flies during the control program:

From the data shown above, it is evident that with the exception of the house fly, the numbers of trapped flies diminished throughout the season. Among the reasons for the increased numbers of house flies is the fact that a mulch of maggot-infested manure was placed about rhubarb and asparagus. The numbers of house flies increased following this.

The reduction in Calliphorids was due to two measures. The greatest source of these flies was from the incinerator at the poultry plant. With the construction of an underground disposal pit for dead birds, an immediate reduction in the number

Table 1.—Abundance of flies throughout season.

Date	*Musca domestica*	*Muscina stabulans*	*Ophyra leucostoma*	*Fannia scalaris*	*Paregle cinerella*	*Sarcophagidae*	*Calliphoridae*	*Misc.*
	Per Cent of Total							
JUNE 12	16.9	18.8	7.2	1.2	6.8	1.8	29.9	17.4
JUNE 26	15.7	29.4	6.6	1.8	7.2	2.2	17.8	19.3
JULY 10	17.9	12.3	33.7	1.2	11.1	3.5	12.9	7.4
JULY 24	44.8	14.9	14.9	1.5	6.9	3.7	4.8	8.7
AUG. 8	64.6	13.4	3.2	1.6	2.4	4.5	3.4	6.9

of blowflies resulted. A second source of blowflies, especially *Cynomyopsis cadaverina* (R.D.), was from a shed used for the storage of poultry manure. This could not be adequately fly-proofed, and not until the manure was removed from the shed was this source of infestation eliminated.

The false stable fly was abundant almost everywhere, but seemed to occur especially near buildings where horses and young stock were maintained.

The latrine fly, *Fannia scalaris*, did not prove to be a pest of any proportions. At no time was there more than 2% of the total catch of this species.

In addition to the value of the fly traps as a means of determining the location and abundance of adult flies, they possess also considerable value as a direct means of control. The following records show the numbers of flies caught throughout the season.

DATE COLLECTED	NUMBER OF FLIES PINTS
June 9	5
12	6
16	5
22	18
29	14.5
July 3	29
10	9
17	25
24	21
31	20
Aug. 8	35
15	23
21	52
Total	262.5

According to Fenton & Bieberdorf, 1936, one pint of flies contains 8500 flies. According to observations based on fifty 25 cc. samples, I calculated that there are 10.8 flies per cc. Of course this would vary greatly with the species, but based on random samples, the above seemed to hold. According to my calculations there would be about 5100 flies per pint. It is evident that the traps, therefore, reduced the fly population by somewhere between 1.3 and 2.2 million flies, to say nothing of the reduction through the elimination of these flies as potential breeders.

The methods used in the attempt to alleviate the fly nuisance included removal of manure at least once a week. Where possible, it was spread immediately. In one instance it could not be spread but had to be stacked. A large canvas was obtained, painted black, and placed over the pile. Observations taken with thermometers indicate that on a day when the air temperature was 88° F. the temperature under the canvas varied from 130° F. on the north side of the pile to 140° F. on the south side. A mass of crawling maggots was found in the grass near the edge of the pile. Within a week after stacking and covering the manure with the black canvas, no evidence of fly maggots could be found. Furthermore, as the canvas was removed to cover new manure, the portion of the manure thereby exposed no longer seemed attractive as breeding media.

Other control measures included the use of electric fly traps in stables and in the piggery. DDT was used against both the adults and the larvae. While very effective against the former, it was not very effective in the treatment of the litter infested with maggots.—4-25-46.

LITERATURE CITED

Fenton, F. A. and G. A. Bieberdorf. 1936. Fly control on the A & M Farms, Stillwater, Oklahoma. JOUR. ECON. ENT. 29: 1003–8.

Howard, L. O. and F. C. Bishopp. 1926. The house fly and how to suppress it. U.S.D.A. Farmers Bul. 1408.

Parman, D. C. 1927. Chemotropic tests with the screw-worm fly. U.S.D.A. Dept. Bul. 1472.

A Laboratory Method of Flea Culture[1]

J. P. LINDUSKA and J. H. COCHRAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

As a part of its general research program on insects of importance to the armed forces, the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine initiated studies on flea repellents in 1942. After reasonably effective methods of protection against fleas were developed by Lindquist *et al.* (1944), the studies were discontinued in favor of more pressing problems. However, the prospects of extended military operations in the Pacific theater during World War II encouraged the reopening of a flea-research program in 1945. To provide the many insects necessary for wide-scale testing, a procedure for rearing fleas was developed which was found to operate with a minimum of effort. A brief description of the method is presented.

The insects colonized were cat fleas, *C. felis* (Bouché), and dog fleas, *Ctenocephalides canis* (Curt.). However, in addition to the above species, the dogs used for hosts were found to be infested with the sticktight flea, *Echidnophaga gallinacea*

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

(Westw.). To obtain a pure infestation of cat and dog fleas it was necessary to rid each new animal of all fleas and to reinfest it with the test species.

Approximately 3000 to 4000 fleas were reared weekly for the repellent and toxicant studies made at this laboratory, and five to eight dogs were used to maintain this production level. These dogs were held in kennels and received no special treatment other than an abundant diet. Throughout the day they were allowed the freedom of their individual runways, but at night were confined in elevated screen cages with hardware cloth floors. The unattached flea eggs that were dislodged from the animals as a result of frequent scratching and shaking were caught on a heavy cloth fastened beneath the floor of the cage. Twice weekly the eggs were recovered from the cloth, and lots of approximately 500 were placed in 1-gallon battery jars or preserving jars containing a 1-inch layer of dry sand. About 1 teaspoonful of dried, powdered blood albumen was added to each jar to furnish food for the emerging larvae. A second feeding, using about the same amount of material, was made at the time the first lot of food was consumed, usually about 3 to 4 days following the hatch. The two feedings were sufficient to carry the insects through to pupation. No food was provided the adults, which were used for test purposes at an age of 5 to 8 days.

Although no special attention was given to determining the optimum conditions for rearing fleas, excessive humidity appeared to reduce hatching success. Consequently, the laboratory culture was maintained at the lowest humidity possible without recourse to special devices.—4-29-46.

LITERATURE CITED

Lindquist, A. W., A. H. Madden, and C. N. Watts. 1944. The use of repellents against fleas. JOUR. ECON. ENT. 37: 485–6.

A New Lacebug in Florida

N. STAHLER, *U.S.D.A., Bureau of Entomology and Plant Quarantine, Agr. Res. Adm.*

A series of tingids collected from beggarticks *Bidens pilosa radiata* Sch.-Bip., by Max R. Osburn at Fort Pierce, Fla., on May 26, 1942, and submitted for determination to the Division of Insect Identification of the Bureau of Entomology and Plant Quarantine, proved to be *Leptopharsa machalana* var. *vinnula* Drake & Hambleton,[1] described as new from this material. In view of its possible economic importance, certain observations have been made at Mr. Osburn's suggestion, and are reported herewith.

The adult (Fig. 1) is completely black except for pale appendages and partially shaded pronotum and hemelytra. It is slow-moving and feeds and oviposits on the under surfaces of leaves, preferring shaded conditions. It has been collected in the field on only two hosts, beggarticks and Caesar's burr, *Urena lobata* L., although a few eggs have been found on the urticaceous weed *Boehmeria cylindrica* var. *drummondiana* Wedd. Typical lacebug injury results from heavy populations.

Collections in the vicinity of Fort Pierce from April to November 1945, inclusive, indicated that breeding was continuous during that period. The population was at its lowest level in September, when many dead adults were observed on the leaves with hyphae of a fungus, *Hirsutella* sp.,[2] protruding from their bodies. Females were two to three times as abundant as males.

In the insectary the tingid has been reared on several varieties of snap and lima beans, but there is no indication that these plants are preferred to its wild hosts. Twenty-four other species of plants were tested as hosts by confining the insects in cells on the leaves, but in no case did they feed or oviposit. These plants included the following: Avocado,

FIG. 1.—*Leptopharsa machalana* var. *vinnula* Drake and Hambleton. Female (×27).

bougainvillaea, cabbage, carrot, collard, cosmos, Crotalaria, lemon, lime, mango, mulberry, Natal plum, *Carissa grandiflora*, oleander, orange, papaya, garden and field peas, pepper, squash, tomato, turkscap, *Malvaviscus*, turnip, watermelon, and zinnia.

In May and June 1945, *Leptopharsa* was reared in the insectary on leaves of beggarticks, and the biology was studied under these conditions. Complete records were obtained on 28 adult females. It was found that copulation may occur the same day as emergence from the last nymphal exuvium, and that the preoviposition period was 2 days. No parthenogenesis was observed. Eggs were laid singly, on end, and were almost completely covered by a black sticky material. The greatest number deposited by a single female was 106, the maximum for a single day being 8. The longest period of oviposition was 41

[1] Drake, C. J., and E. J. Hambleton: 1946 New species and new genera of American Tingidae (Hemiptera). Wash. Biol Soc. Proc. 59: 13.

[2] Determined by J. A. Stevenson of the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering.

days. The maximum longevity record for an adult (female) was 56 days, while the average duration, in days, of each immature stadium in from 14 to 42 specimens was as follows: Egg, 9.2; first instar, 1.9; second instar, 1.9; third instar, 1.8; fourth instar, 2.3; fifth instar, 3.2.

The average size (in millimeters) (length by width) of 20 specimens of each stage was as follows: Egg, 0.48×0.21; first instar, 0.52×0.21; second instar, 0.69×0.26; third instar, 0.83×0.35; fourth instar, 1.03×0.48; fifth instar, 1.44×0.65; adults (including wings)—male, 2.04×0.65; female 2.21 ×0.70.

DDT for Control of the Biting Sheep Louse

H. E. PARISH and C. A. RUDE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The biting louse of sheep, *Trichodectes ovis* (L.), can be distinguished from the sucking louse of sheep, *Linognathus pedalis* (Osborn), by its size, shape, color, and the place most frequented on the body of the host. The sucking louse is larger, rather blue in color, similar in shape to the short-nosed cattle louse, *Haematopinus eurysternus* (Nitz.), and generally inhabits the legs below the true wool. The biting louse is minute in size, with a large red head and pale brownish body, and is found on the body of the sheep, generally near the skin.

In spite of its minute size, the biting louse is often more injurious than the sucking louse. This parasite not only causes intense irritation by crawling on the animal, but it injures the wool by weakening the fibers. Heavily infested animals constantly bite themselves, scratch, and rub against objects in an attempt to relieve the irritation caused by the lice. This causes the strands of wool that have been cut by the lice to be pulled loose so that the animal appears "taggy." Sheep infested with this parasite not only lose body weight but also lose much of their wool. When animals with ragged fleece are noted in a herd, they should be examined for lice, which will usually be located on or near the skin.

EXPERIMENTAL DATA.—On February 6, 1945, preliminary tests were initiated to determine the value of DDT dissolved in soluble pine oil[1] in controlling biting sheep lice. One of these tests involved 200 head of purebred Corriedale yearling sheep in full fleece that were heavily infested with lice. Many of these animals had "slick sides," while others were "taggy" in appearance. The animals were dipped in a solution containing 0.2 per cent of DDT made by diluting *Stock 1235* (prepared as described in a later paragraph). Periodic examinations of these treated animals over a period of approximately 3 months revealed no live lice.

A similar test was made on February 14, when 50 sheep in full fleece, with an equally heavy infestation, were dipped in the same solution. No live lice were found when these animals were observed, and no harmful effects on the wool or animals were in evidence.

Since such outstanding results were obtained in these preliminary tests, a more extensive field test was conducted to determine the value of *Stock 1235* in controlling biting lice of sheep. During the first half of May, 1519 sheep and lambs were dipped in a solution containing 0.2 per cent of DDT made by diluting *Stock 1235*. These animals were on the same ranch where the early preliminary tests were conducted. The lambs ranged in age from a few days to approximately 2 months. The owner reported that no more lambs were weaned by their mothers following dipping than is usual in the routine handling of ewes and lambs.

No live lice had been found on these animals by the owner or by the investigators up until the last of July. However, it will be necessary to maintain a close check on the herd for an indefinite period to determine whether this parasite may be reestablished by infested animals that may have been missed in the round-up.

PREPARATION OF *Stock 1235*.—To prepare *Stock 1235*, one part of technical DDT and five parts of soluble pine oil by weight are put in a tight container and shaken vigorously until the DDT is dissolved. Placing the container in warm water will greatly decrease the time required for the DDT to go into solution. This solution is stable under ordinary conditions, but a small amount of DDT may appear in the bottom of the container at very low temperatures. Upon bringing the solution back to room temperature the DDT will slowly dissolve.

PREPARATION OF DIP.—A dip containing approximately 0.2 per cent of DDT requires 10 pints of *Stock 1235* to 100 gallons of water. The dip should be well stirred before using. Since this stock does not make a satisfactory emulsion in alkaline water, it is desirable to test the water with a small amount of stock to determine whether they will mix properly. A single ducking is all that is required for a thorough wetting of an animal.—5-27-46.

[1] This is a water-miscible pine oil conforming to Navy specifications, CS69-38.

Lizards Feeding on Ants in Utah

GEORGE F. KNOWLTON and WILLIAM P. NYE,[1] *Utah Agricultural Experiment Station, Logan*

Ants are directly responsible for a reduction in the livestock carrying capacity of Utah range lands. Harvester ants, and in particular *Pogonomyrmex occidentalis* (Cresson), clear all vegetation from large spots surrounding each of their nests. Thousands such large bare spots are cleared off by ant colonies on range land and in alfalfa fields in Utah. Harvester ants also reduce range forage by bringing to their nests large numbers of seeds and plant stems. The bare spots around *P. occidentalis* mounds range in diameter from 10 to 43 feet. Other injurious ants make nests in lawns, gardens, build mounds which damage mowing equipment in fields, attack wood, attend injurious species of aphids and related honeydew producing insects. Although ants confer some benefits by consuming dead and decomposing insects and other small organisms, they are economically undesirable from the standpoint of crop and livestock production in Utah. Cole[2] in 1942 recorded 104 species, subspecies, and varieties of ants as occurring in Utah.

An examination of 1462 stomachs of 16 species and subspecies of lizards, collected in Utah since June, 1930, showed they contained a total of 14,753 ants. Many other injurious and undesirable insects also were present.

[1] Research professor and graduate assistant, respectively.

[2] Cole, A. C., Jr., Ants of Utah, Amer. Midland Nat., 28: 358–388, 1942.

Table 1.—Number of ants found in stomachs of 12 lizard species.

COMMON NAME	SCIENTIFIC NAME	NUMBER STOMACHS EXAMINED	STOMACHS CONTAINING ANTS	TOTAL ANTS
Banded gecko	*Coleonyx variegotus* (Baird)	2	0	0
Western collared lizard	*Crotaphytus collaris baileyi* Stejneger	103	4	20
Leopard lizard	*Crotaphytus wislizenii* B.-G.	110	1	1
Chuckwalla	*Sauromalus obesus* (Baird)	2	0	0
Desert gridiron-tailed lizard	*Callisaurus draconoides ventralis* (Hallowell)	35	3	10
Brown shouldered uta	*Uta stansburiana stansburiana* (B.-G.)	2349	601	1972
Rocky Mountain tree uta	*Urosaurus ornatus wrighti* Schmidt	45	11	35
Stejneger's blue-bellied lizard	*Sceloporus elongatus* Stejneger	96	46	261
Sagebrush swift	*Sceloporus graciosus graciosus* (B.-G.)	1239	631	7470
Desert scaly lizard	*Sceloporus magister* Hallowell	49	29	755
Western blue-bellied lizard	*Sceloporus occidentalis biseriatus* (Hallowell)	13	5	74
Girard's short-horned hornedtoad	*Phrynosoma douglassii ornatissimum* (Girard)	65	54	1908
Desert hornedtoad	*Phrynosoma platyrhinos* Girard	57	51	2186
Desert whiptail lizard	*Cnemidophorus tesselatus tesselatus* (Say)	468	26	61
Sonoran racerunner	*Cnemidophorus sexlineatus perplexus* (B.-G.)	34	0	0
Western skink	*Eumeces skiltonianus* (B.-G.)	4	0	0
Total		4671	1462	14,753

Stomachs of only four of the lizard species contained no ants. The chuckwalla feeds chiefly on flowers, buds, and leaves of plants. Two stomachs of the banded gecko, four of the western skink and 34 stomachs of the sonoran race runner held no ants in recognizable condition. The latter species and the desert whiptail lizard feed more commonly on caterpillers, beetles, grasshoppers, and other insects of larger size than most of the common ants.

The horned toads feed extensively on ants. Of 65 stomachs of Girard's horned toad examined, 54 contained a total of 1908 ants. Examination of 57 stomachs of the desert horned toad revealed 2186 ants in 51 of the stomachs.

Desert scaly lizards had fed on ants to the extent that 755 were counted in 29 of the 49 stomachs examined.

The sagebrush swift is so common as to be important in control of range insects in many brushy areas. At Blanding, 1662 ants were contained in 107 of the 185 stomachs taken, At Cedar, in Emery County, 850 ants were recognized in 121 of the 196 stomachs collected, while at Kanab, 909 ants were present in 70 of the 123 stomachs. Collections at Mt. Carmel revealed 552 ants in 43 stomachs of the 80 sagebrush swifts collected.

In a rabbitbrush-sagebrush pasture west of Orem, in Utah County, in which the sagebrush swift was extremely abundant, 3497 ants were recognized in 290 of the 655 *S. g. graciosus* stomachs examined. It was estimated that more than 1000 swifts per acre were present in brushy margins of this pasture. A total of 7470 ants were found in the stomachs of 631 *Sceloporus g. graciosus*, out of a total of 1239 stomachs examined from the above named localities. From a study of 2191 sagebrush swift stomachs taken in Utah, Knowlton, *et al.* recorded a total of 11,472 ants out of a total of 12,267 Hymenoptera recognized.

The brown-shouldered uta is probably the most abundant lizard over much of the arid semidesert area in Utah. The senior writer has estimated that from 100 to more than 300 specimens of this lizard often occur per acre on favorable range feeding areas of Tooele and Box Elder Counties. Of specimens collected west of Skull Valley, in the general vicinity of Delle, 541 ants were found in 147 of the 464 stomachs examined. In the Dolomite area 514 ants occurred in 183 of the 643 stomachs. At Iosepa in Skull Valley, Tooele County, 171 ants were recorded from 75 stomachs out of 653 examined. At Timpie, 646 ants were present in 196 of the 589 uta stomachs. The total of the above shows 1972 ants still in recognizable condition in 601 of the 2349 stomachs. This common uta evidently feeds less generally on ants than horned toads and sagebrush swifts.

As shown in table 1, this study revealed the occurrence of 14,753 ants in recognizable condition in 1462 of the 4671 lizard stomachs examined. From this the writers would conclude that insectivorous lizards are of importance in the biological control of ants in many range areas of Utah.—4-1-46.

Birds Feeding on Ants in Utah

G. F. KNOWLTON, R. S. ROBERTS and S. L. WOOD,[1]
Utah Agricultural Experiment Station, Logan

Ants of many kinds occur in Utah. Cole (1942) recorded 104 species, subspecies, and varieties as recognized from this state. A number of the species are serious pests of range, farm land, orchard, and household.

Studies conducted during the past twelve years

[1] Research professor, graduate and undergraduate assistants in entomology.

Table 1.—The following table lists the 108 species of birds, the stomachs of which were examined in this study.

Bird Species	Ants Eaten	Stomachs Containing Ants	Stomachs Examined
Snowy egret	—	—	1
American bittern	—	—	3
Western red-tailed hawk	—	—	10
Red-shouldered hawk	—	—	2
Swainson hawk	—	—	22
Marsh hawk	—	—	1
Eastern sparrow hawk	22	6	252
Dusky grouse	165	1	1
Sage hen	2009	12	17
California quail	1	1	7
Ring-necked pheasant	35	6	14
Killdeer	16	4	13
Long-billed curlew	—	—	2
Spotted sandpiper	4	1	1
Western willet	—	—	1
Wilson snipe	—	—	2
Avocet	—	—	2
Wilson phalarope	—	—	2
California gull	—	—	2
Western mourning dove	2	1	31
California cuckoo	—	—	1
Road-runner	—	—	1
Burrowing owl	—	—	6
Long-eared owl	—	—	1
Nighthawk	1212	3	6
Nuttall poor-will	—	—	2
Rufus hummingbird	—	—	1
Western belted kingfisher	—	—	1
Red-shafted flicker	5134	16	16
Lewis woodpecker	—	—	6
Red-naped sapsucker	320	7	8
Williamson sapsucker	173	5	5
Hairy woodpecker	21	2	3
Downy woodpecker	—	—	1
Eastern kingbird	140	9	22
Arkansas kingbird	472	19	121
Say phoebe	17	6	23
Little traill flycatcher	2	1	3
Hammond flycatcher	11	3	4
Wright flycatcher	14	3	5
Olive-sided flycatcher	—	—	1
Great Salt Lake horned lark	127	40	207
Violet-green swallow	7	5	14
Bank swallow	—	—	1
Rough-winged swallow	325	1	9
Barn swallow	167	13	59
Cliff swallow	80	6	7
American magpie	16	4	26
American raven	—	—	7
Piñon jay	10	1	3
Clark nutcracker	—	—	1
Long-tailed chickadee	24	8	23
Mountain chickadee	2	1	1
Lead-colored bush-tit	2	1	7
Rocky Mountain creeper	8	2	3
Dipper	—	—	1
Western house wren	3	2	3
Desert bewick wren	—	—	1
Canyon wren	2	1	2
Rock wren	1094	26	95
Western mockingbird	—	—	2
Catbird	—	—	3
Sage thrasher	245	27	70
Audubon hermit thrush	26	6	6
Rocky Mountain olive-backed thrush	6	1	1
Mountain bluebird	573	73	194
Townsend solitaire	29	4	6
Western golden-crowned kinglet	2	2	7
Western ruby-crowned kinglet	3	1	7
American pipit	23	12	101
White-rumped shrike	15	7	66
Oregon warbling vireo	2	1	1
Rocky Mountain orange-crowned warbler	3	1	9
Rocky Mountain yellow warbler	39	13	19
Rocky Mountain Audubon warbler	46	9	34
Macgillivary warbler	2	1	3
Northern pileolated warbler	8	3	15
English sparrow	—	—	33
Bobolink	—	—	1
Western meadowlark	225	43	202
Yellow-headed blackbird	7	3	15
Red-winged blackbird	190	14	103
Bullock oriole	19	5	15
Brewer blackbird	119	31	140
Western tanager	9	4	4
Rocky Mountain black-headed grosbeck	—	—	3
Lazuli bunting	6	1	3
Cassin purple finch	1	1	2
House finch	2	2	47
Northern pine siskin	12	1	3
Arkansas goldfinch	—	—	4
Green-tailed towhee	—	—	3
Spurred towhee	6	1	2
Lark bunting	3	2	3
Nevada Savannah sparrow	—	—	11
Western lark sparrow	41	15	98
Western vesper sparrow	175	40	111
Northern sage sparrow	89	17	45
Shufeldt junco	15	10	42
Pink-sided junco	5	1	2
Gray-headed junco	10	3	4
Western tree sparrow	—	—	1
Western chipping sparrow	277	68	310
Oregon white crowned sparrow	10	6	17
Gambel sparrow	162	40	132
Slate-colored fox sparrow	—	—	1
Lincoln sparrow	4	2	3
Song sparrow	—	—	4
	14046	688	3007

[1] Most of the above common bird names are those used by William H. Behle in his "Check-list of the birds of Utah." *The Condor*, 46(2): 67–87. 1944.

have revealed that ants constitute an important item in the diet of many range and farm land birds. During the present study an examination has been made of 3007 stomachs taken from 108 species of birds. Of this number, 688 stomachs of 70 bird species contained a total of 14,046 recognizable ants.

In the red-shafted flicker, one stomach collected at Smithfield, Utah, July 15, 1941, contained a total of 785 adult ants besides 932 ant larvae and pupae, largely *Formica fusca* var. *neorufibarbis* Emery (Det. A. C. Cole). Another red-shafted flicker taken at Clover, Utah, September 30, 1939, contained 340 adult and 135 pupal ants. At this locality nearly two dozen of these flickers and almost as many Lewis woodpeckers, were present in an orchard and in tall poplar trees along the highway. Another flicker collected at Utah Hot Springs, May 3, 1940, held 408 adult and 93 pupal ants. A total of 5134 ants, of which 1406 were larvae and pupae, were recognized in the stomachs of 16 red-shafted flickers. All specimens collected contained ants.

One nighthawk stomach collected in the southern part of Skull Valley, Tooele County, Utah, on July 26, 1941, contained 1200 flying ants besides other flying insects. A sage hen collected near Bennmore, Tooele County, on July 24, 1941, contained 38 ants in its crop and 585 ants in its stomach. Another sage hen collected nearby had 122 ants in the crop and 350 recognizable in the gizzard. A rock wren stomach, collected at Fishers Pass, west of the town of Clover, among sage and juniper on July 26, 1941, held 658 winged ants, the majority of the specimens being small winged males. A rough winged swallow collected nearby, in Clover Canyon on the same date, contained remains of 325 flying ants in its stomach. —4-1-46.

Toxicity of Some N-Substituted Phthalimides to Codling Moth Larvae

E. H. SIEGLER and S. I. GERTLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In connection with a search for promising insecticides certain N-substituted phthalimides were tested in the laboratory against larvae of the codling moth, *Carpocapsa pomonella* (L.).

These compounds were made by allowing one mole of phthalic anhydride to react with 1 mole of amine and subsequent heating with splitting off of water to form the imide. The reaction is represented by the equations given below.

The radicals represented by R consisted of either aliphatic or aromatic groups. Some of the aromatic compounds had various groups substituted on the benzene ring.

In conformity with the usual laboratory procedure, the compounds were evaluated by the apple-plug method. Each compound was used at the rate of 4 pounds to 100 gallons of the carrier, which consisted of water 80 per cent and ethanol (95 per cent) 20 per cent, by volume. A single codling moth egg, ready to hatch, was used to infest each apple plug. From 91 to 109 apple plugs were used in each test of the substituted phthalimides, 473 plugs in the lead arsenate tests, and 485 for the check tests.

The data obtained in this study are given in table 1. Among the compounds tested, N-1-naphthylphthalimide gave the best results. This compound, however, was less effective than lead arsenate, and the other substituted phthalimides had little or no toxicity to codling moth larvae.—4-18-46.

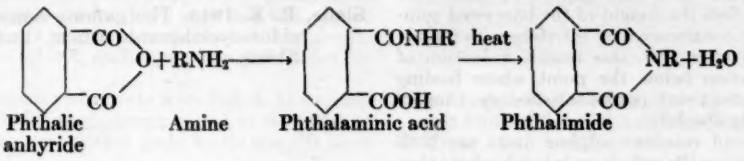


Table 1.—Results of Tests of Some N-Substituted Phthalimides against Codling Moth Larvae.

NAME OF COMPOUND	FORMULA	PERCENTAGE OF APPLE PLUGS	
		Wormy	Stung
N-1-Naphthylphthalimide	$C_6H_4(CO_2)NC_{10}H_7$	69	0
N-(*o*-Chlorophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4Cl$	80	1
N-Anilinophthalimide	$C_6H_4(CO)_2NNHC_6H_5$	81	1
N-(*p*-Nitrophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4NO_2$	84	0
N-*m*-Tolylphthalimide	$C_6H_4(CO)_2NC_6H_4CH_3$	86	0
N-*p*-Tolylphthalimide	$C_6H_4(CO)_2NC_6H_4CH_3$	87	0
N-2-Naphthylphthalimide	$C_6H_4(CO)_2NC_{10}H_7$	87	1
N-Benzylphthalimide	$C_6H_4(CO)_2NCH_2C_6H_5$	88	0
N-(2,5-Dichlorophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_3Cl_2$	89	0
N-(m-Chlorophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4Cl$	89	1
N-Cyclohexylphthalimide	$C_6H_4(CO)_2NC_6H_{11}$	90	0
N-(5-Nitro-*o*-tolyl)phthalimide	$C_6H_4(CO)_2NC_6H_3(CH_3)NO_2$	90	1
N-(2-Hydroxyethyl)phthalimide	$C_6H_4(CO)_2NC_2H_4OH$	91	0
N-(*o*-Hydroxyphenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4OH$	92	1
N-Octylphthalimide	$C_6H_4(CO)_2N(CH_2)_7CH_3$	94	0
N-Isobutylphthalimide	$C_6H_4(CO)_2NCH_2CH(CH_3)_2$	95	0
N-Isopropylphthalimide	$C_6H_4(CO)_2NCH(CH_3)_2$	95	0
N-Ethylphthalimide	$C_6H_4(CO)_2NC_2H_5$	96	0
N-(*m*-Nitrophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4NO_2$	96	0
N-(*p*-Bromophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4Br$	97	0
N-Propylphthalimide	$C_6H_4(CO)_2NC_3H_7$	97	0
N-(*p*-Chlorophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4Cl$	97	1
N-Methylphthalimide	$C_6H_4(CO)_2NCH_3$	97	1
N-(*o*-Nitrophenyl)phthalimide	$C_6H_4(CO)_2NC_6H_4NO_2$	97	2
N-*o*-Tolylphthalimide	$C_6H_4(CO)_2NC_6H_4CH_3$	98	0
Lead arsenate[1]	—	56	7
Check (untreated)[1]	—	92	0

[1] Average for 5 tests.

Control of Aphids on Spinach with Hexachlorocyclohexane[1]

DWIGHT ISELY and FLOYD D. MINER,
University of Arkansas, Fayetteville

The control of the green peach aphid, *Myzus persicae* (Sulz.), on spinach is difficult, not because of any special resistance of the aphid to insecticides, but because of the problem of actually hitting the insect with dust or spray. The low growing character of spinach, with the foliage nearly flat on the ground, makes it impossible to secure contact with more than a small proportion of the aphids feeding on the underside of the leaves. In Arkansas this difficulty is increased since almost all of the spinach grown is of savoy-leaved varieties. A second problem is introduced if the spinach crop is canned. There is no tolerance for aphids in the canned product. The number of aphids in a field may be so small that they do not affect the weight of the harvested spinach, but their occurrence may interfere with its sale as a canning crop. For this reason reduction of aphid population below the point where feeding injury is apparent may not be satisfactory. Control must be nearly absolute.

Rotenone and rotenone-sulphur dusts are both effective in killing the aphids on spinach where they come in contact with the aphids. Under field conditions, however, dusting with these insecticides has apparently little value in reducing the aphid population. Nicotine might be expected to be more effective but during the growing season for spinach temperatures are relatively low—generally too low for effectiveness of this insecticide.

In small scale experiments, dusting with the gamma-isomer of hexachlorocyclohexane,[2] has produced strikingly effective control. While it is not possible to secure better coverage with this insecticide than with the others, it is effective against aphids on spinach, apparently because it kills not only by contact but by fuming action. In his description of this insecticide, Slade (1945) has pointed out that it is not only a stomach poison and contact insecticide but also a fumigant. In greenhouse experiments, dusts containing 0.5 per cent, 0.75 per cent and 1.5 per cent of the gamma-isomer applied on heavily infested plants produced 100 per cent mortality. Not all of the aphids were killed immediately; they continued dropping from the leaves for over a day. The plants appeared to be protected from reinfestation for over 2 weeks. Artificial reinfestation was not attempted. The conditions were not typical of the field for not only was the number of plants dusted small, but the amount of dust used was heavy and the temperature was 75° F. or above.

A limited field test of hexachlorocyclohexane for control of aphids on spinach was made early in March. Dusts including 0.75 per cent of the gamma-isomer were applied on two series of plots of two each. On the four plots the average reduction of aphid population was 95.8 per cent of the population present before dusting. If the increase of aphids on the check plots is taken into account the reduction of infestation was 98.5 per cent. This was the only dust material applied which was in any degree effective. Counts were made on one pair of plots 2 days after the application was made. On the second pair of plots counts were made 6 days after the dust was applied. The temperature when applications were made was 55° F. and 58° F. respectively. The amount of dust used was heavy, 70 pounds or more of the dilute dust to the acre. However, no attempt has been made to determine the acre dosage necessary. All the dusts were diluted with pyrophyllite.

Insecticide tests have been made with hexachlorocyclohexane to check on its effectiveness against other aphids. For control of the turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis), on mustard it appeared to be fully as effective as against the spinach aphid. Here the problem of control is similar and the plants are close to the ground. When tried to control the English grain aphid, *Macrosiphum granarium* (Kby.), on oats it was less effective, possibly because the plants were taller and the resulting concentration of gas about the aphids might have been less.—5-1-46.

[1] Research Paper No. 814 Journal Series, University of Arkansas. Published with the permission of the director of the Arkansas Agricultural Experiment Station.
[2] Supplied by E. I. du Pont de Nemours & Co.

LITERATURE CITED

Slade, R. E. 1945. The gamma-isomer of hexachlorocyclohexane. Chem. and Ind. **40**: 314–9.

Insects in Shelled Peanuts in Relation to Storage and Bagging[1]

THEODORE L. BISSELL and MINTER DU PREE,
Georgia Experiment Station, Experiment, Georgia[2]

This study covers two phases of insect infestation, the population "naturally" occurring in shelled peanuts and a comparison of two bagging materials for protective qualities.

INFESTATION.—To secure information on the insect infestation of shelled peanuts nine lots, totaling 50 pounds, secured from eight shelling plants located in Georgia, were examined January to April, 1946. The first was of Runner peanuts, all others were Spanish.

Upon receipt the peanuts were sifted over an 8-mesh screen and all insects seen were removed. The peanuts were put in tight glass jars and held to determine if anything might develop from eggs or other small forms overlooked at first. Cursory examinations were made once a month and a final thorough sifting was made in April.

A list of the insects collected and other pertinent data are given in table 1. In six lots of peanuts there were 38 insects, 20 alive and 18 dead; three lots did not yield any. Thirteen known kinds of insects are included; of these the saw-toothed grain beetle (1 live beetle), the fig moth (1 live larva), and the flour beetle (1 cast skin) are very destructive to shelled peanuts. The psocids (17 found in two lots at the last examination), flat grain beetle, cigarette beetle, and sap beetle are suspected of being injurious; all the others are considered accidental inclusions.

The most heavily infested lot (excepting those with psocids) was No. 3 which had been stored more than three months between shelling and examination. In all the lots which were examined and caged soon after shelling the insect infestation was much lower.

BAGGING MATERIALS.—After the nine lots of peanuts were sifted to remove all visible insects

[1] Paper No. 153, Journal Series, Georgia Experiment Station.
[2] Cooperating with the National Peanut Council.

they were mixed and used in a bagging test. Two kinds of material were used, 10 ounce jute counting 11 or 12 threads to the inch, such as is regularly used for shelled peanuts, and a coarse aeroplane cloth of heavy cotton counting 60 threads by 104 to the inch. Bags were made 11 in. by 8 in., each holding 2 pounds of peanuts. The bags were tied at the neck with one string.

Two storage places were used, a barn containing a variety of feeds and a cabinet with temperature controlled at 80 to 85° F. and humidity controlled at 60 to 70 per cent. Five jute bags and five of cotton were placed in each location, the bags touching, jute and cotton alternating. In the barn the bags of peanuts were protected from rats with hardware cloth. A supply of insects was put in the cabinet for infestation but in the barn the natural infestation was used. The peanuts were bagged and stored on April 26.

The peanuts were left in the barn 8 weeks, those in the cabinet 9 weeks. Then each bag was opened and the insects sifted out and counted. The results are given in table 2, each figure being the count for five bags.

Twelve species of insects were found. Disregarding the psocids, which were counted in only part of the bags, the saw-toothed grain beetle was the most

FIG. 1.—Jute bag, above, and cotton bag, below, with saw-toothed beetles and red flour beetles and larvae.

Table 1.—Insects found in shelled peanuts, by lots and dates of examination. All forms adult except as noted.

WEIGHT IN OZ.	DAYS BETWEEN SHELLING AND SHIPPING	DATES EXAMINED	INSECTS	COMMON NAMES
100	0	Jan. 29	1 beetle leg	
			1 larva, beetle or moth	
		Apr. 19	None	
79	0	Jan. 29	None	
		Feb. 28	1 *Carpophilus* sp.	sap beetle
		Apr. 19	1 *Oryzaphilus surinamensis*[3]	saw-toothed grain beetle
			7 Psocids[3] (+1 dead)	
109[1]	100 approximate	Jan. 29	1 Carabidae	
			1 larva, *Carpophilus* sp.	sap beetle
			1 larva, *Ephestia cautella*[3]	fig moth
			1 *Sitophilus oryzae*	rice weevil
			1 larval skin, *Tribolium* sp.	flour beetle
		Feb. 28	1 beetle larva[3]	
		Apr. 19	2 *Laemophloeus* sp.[3]	flat grain beetle
			1 *Lasioderma serricorne*	cigarette beetle
79	1	Jan. 29	None	
		Apr. 19	1 *Stephanopachys punctatus*	a wood borer
			8 Psocids[3] (+1 dead)	
77	0	Jan. 29	None	
		Apr. 19	1 *Sitotroga cerealella*	Angoumois grain moth
86	1	Feb. 4	None	
		Apr. 19	None	
56	6	Mar. 25	None	
		Apr. 19	None	
96[2]	?	Apr. 19	None	
104	18	Apr. 23	1 *Tenebrio* sp.	meal worm
			5 Anthomyidae	

[1] Stored by sheller as shelled nuts from October to January, conditions of storage not stated.
[2] Was fumigated soon after shelling and kept in a friction-top can until examination in April.
[3] Live insects.

Table 2.—Insects found in shelled peanuts according to bagging material and place of storage.

	Jute Bags		Cotton Bags	
	Barn	Cabinet	Barn	Cabinet
Saw toothed grain beetle				
Adults	245	47	14	
Larvae and pupae	369	17	46	
Red and confused flour beetles				
Adults	19	62	1	4
Larvae and pupae		9	1	2
Cadelle—adults	2			
Larvae	28		1	
Flat grain beetle	10			
Small-eyed flour beetle	1		1	
Dermestidae—larvae	13			
Rice weevil		5		
Unknown beetle larva	1			
Almond moth—pupae		7		
Larvae	3	11		
Indian meal moth				
Larvae	27			
Psocids[1]		202		4
Totals	718	360	64	10

[1] Counts of psocids were made in only four jute and four cotton bags.

common insect. A mite was also present but none was counted.

Every jute bag had insects, the number ranging from 87 to 166 in the barn and from 15 to 57 in the cabinet. The peanuts showed considerable webbing from lepidopterous larvae that had fed and left the bags for pupation. An examination of the texture, shows that the meshes are large enough to admit the beetles and larvae, hence, there is ample reason for infestation. When clean peanuts are stored in 10 ounce jute bags they may readily become infested from outside sources.

Of the 10 cotton bags 1 in the barn and 3 in the cabinet had no insects, and 1 other had none except psocids. Of the five remaining cotton bags 2 had open corners due to imperfect sewing and a third had a loosely tied top; these 3 contained 66 of the 74 insects found in all the cotton bags.

Conclusion.—The preliminary infestation counts showed that recently shelled peanuts have relatively few insects. This indicates that most of the insect pests commonly found in shelled peanuts gain entrance after shelling.

The bagging test showed that peanuts stored in jute bags will become heavily infested and that the infestation can be materially reduced or eliminated by storing in heavy cotton bags.—7-14-46.

Concerning the Pittsburgh Meetings

The following letter, of interest to members of the Association, has been received by the Secretary:

I understand that arrangements have been made for the American Association of Economic Entomologists to hold their meeting in Pittsburgh in early December. Speaking in behalf of the Museum, I wish to welcome you, and I hope that the members of the Association will be able to visit the Museum as much as possible during their stay here. We are arranging to keep the Museum open on the evening of December 11 up to 10:00 P.M. I believe also that the International Art Exhibit will be open at the same time, and some of your members, or perhaps their wives, will be particularly interested in this exhibition.

Dr. Sweadner, our Curator of Entomology, is making arrangements to provide every facility should any of your members wish to consult the entomological collections. If some of them wish to visit the Lab in the evenings on days when the Museum closes at 6:00 P.M., Dr. Sweadner can make arrangements to accommodate them.

With pleasant anticipations of your visit, I am

Yours sincerely,

O. E. Jennings

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 39 August, 1946 No. 4

Entomological Publications

DURING the past several years there has scarcely been a meeting of any entomological group, large or small, where the matter of increased facilities for publication in the field of entomology has not been discussed. This has been particularly true of groups which have discussed the "Needs of Entomology," "Post-War Planning" and other general considerations of the subject of economic entomology as a field of endeavor.

Recently there have been at least two suggestions for the establishment of new periodical publications in restricted fields of entomology and in a field more general than the present scope of the *Journal*. The entomological public has been, as a result of the agitation, pretty well convinced that additional publication media are badly needed by the profession. Let us consider the facts.

The *Journal* has, in the past six years, rejected certain manuscripts sent to it for publication. Rejection has been based on a variety of causes. A few papers were so poorly prepared that they were frankly impossible; others almost as bad were published for reasons which will appear. A few were judged to lie outside the established field of the *Journal* although the tendency has been to widen the scope of the *Journal* wherever possible. A dozen or more papers have been held up because the authors were not members of the Association; all but three or four of these have later been accepted and published when the authors applied for membership. A liberal estimate of the volume of rejected material can not exceed 50 *Journal* pages in the past six years; possibly half that total would be more nearly correct. It will be evident from this that the *Journal* has not failed to provide the publication facilities it has been called upon to provide, within its publication scope.

In the year 1940 the *Journal* contained 960 pages; it has declined steadily to date and in 1945 it contained only 752 pages, even though it published practically all the material submitted to it. The total in 1946 will probably be up a trifle but not very much. In the fall of 1945 the December *Journal* was delayed because there was not enough material on hand to make up the issue. It is still necessary to keep watch over the reserve to be sure that there will be a December issue on time this year for the same reason —possible scarcity of material. Recently a complaint was sent in because we have published DDT articles to the practical "exclusion" of articles on other insecticides and other subjects. The reader of the *Journal*, as opposed to the contributors to the *Journal*, may have a valid complaint. But the contributor has had ample publication opportunity. He just has not made use of it.

It is the belief of the writer that the *Journal*, in spite of a distinct increase in publication costs provided in a newly negotiated contract, can handle up to 1500 pages per year without overtaxing the resources of the Association. That would be easily twice as much as has ever been published in one year, if allowance is made for the fact that business material would not be increased materially in the larger *Journal*.

A few years ago the Association voted to sponsor a series of more voluminous publications, "critical reviews," possibly monographs, and similar material. These might have been published separately or as long *Journal* articles, 100 pages or more as would have been decided for each publication. Within the five-year period not a single article of this type has been submitted even though they have been solicited in several instances.

In view of these facts the question

naturally arises, "Where is all this material which is in pressing need of publication?" The answer is not apparent. It is apparent to the writer that the Association may well consider the full utilization of its present facilities before it embarks on new publications which would be more expensive, as separate publications, than the same material would cost published in the *Journal*. If those new publications contemplate the inclusion of material not now included in our publication scope, let us enlarge our scope; let us arrange the material in sections devoted to different phases of the field of interest of our readers and supporters and thus serve their interests adequately, in so far as publication facilities are concerned, and conserve the resources of their Association at the same time. And let us consider the fact that new publications in supporting fields are being established and others are growing; such a magazine as the new "Agricultural Chemicals" will inevitably use some of the material which has formerly gravitated to the *Journal*. And properly so. Federal and state publications, greatly reduced in our field during the war period, may be expected to divert some of the *Journal* material of the past few years.

The factual material given above is certainly worth the consideration of those who may read it; the opinions show merely how the facts affect the thinking of the writer.

L. M. PEAIRS

OBITUARY

Rufus Hiram Pettit 1869-1946

Rufus Hiram Pettit, B.S., D.Sc., Consulting Entomologist, Michigan State College, died June 1, 1946. Dr. Pettit was born at Baldwinsville, New York, January 11, 1869. He graduated from Baldwinsville Academy in 1887 and after serving two years as an apprentice in a local machine shop, he entered Cornell University. After one year's college work he served a year as anatomist at Ward's Natural Science Establishment, Rochester, New York; then he returned to the University and specialized in Entomology receiving his B.S. in Agriculture in 1895. During this period he enjoyed the privilege of serving as a personal assistant to Professor J. H. Comstock and made many line drawings illustrating wing venation which were used in the "Manual for the Study of Insects."

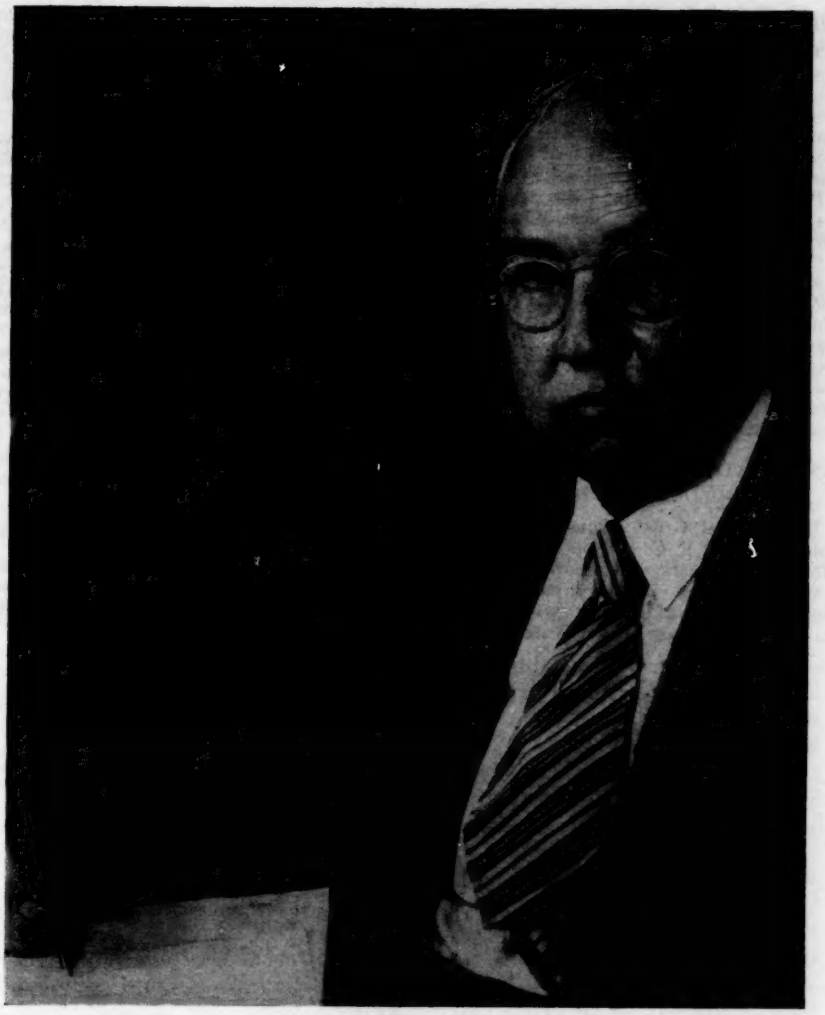
Immediately after graduation he received an appointment as Assistant State Entomologist of Minnesota, under Dr. Otto Lugger, where he remained for over a year. On January 1, 1897, he was appointed Instructor of Zoology and Assistant in Entomology in the Experiment Station, Michigan Agricultural College. Entomology was separated from Zoology in 1908 forming a new department with Professor Pettit in charge of the Department and serving also as Acting Entomologist on the Experiment Station.

Dr. Pettit was an expert photographer and made thousands of illustrations of insects and of the work of insects. Many of these illustrations were used in current publications and later a large number found their place in different text books. He also had the ability to make accurate pen and charcoal drawings. A number of the pen illustrations of animal parasites in use today are his drawings.

His skill as a mechanic was applied to making insect displays among which are about 30 Harvard cases illustrating the injuries caused by insects to Michigan trees together with a series of plaster casts depicting the work of insects on fruits and vegetables.

Dr. Pettit was a naturalist of the old school but his special love was for Entomology. In his capacity as head of the department he trained many young people to have an understanding of the subject and its application to their own lives. He took an active part in shaping the course of the institution and, as a result, he saw that all students interested in agriculture had training in entomology. He was a popular teacher because of his deep understanding of human nature and because of his ability to present an obscure subject in such a way that the student retained the fundamentals long after the details had faded. He constantly stressed the principles of applied entomology and was always seeking new approaches to old problems. He was a member of the Lambda Chi Alpha Society, Sigma Xi and Alpha Zeta.

Dr. Pettit wrote on many subjects pertaining to Entomology. His first publication his thesis, "Studies in Artificial Cultures of Entomogenous Fungi," was prepared with the idea of presenting it as a thesis toward the degree "B.S. in Agriculture." When finished it proved to be outstanding and was published by Cornell University as Experiment Station Bulletin 97, 1895. The subject deals with diseases among insects caused by fungi. This bulletin, in which several new species were described, was illustrated with pen drawings made during the study. The bulletin remains today outstanding in the field of insect diseases. The last outstanding bulletin, Michigan State College Special Bulletin 183 on "Common Pests of Field and Garden Crops" ran over 100,000 copies and is still demanded by the people of the state. Included in the list of publications Dr. Pettit wrote over thirty bulletins mostly in the field of insect control besides issuing an



Rufus Hiram Pettit 1869-1946

annual spray calendar and numerous short articles for different scientific journals and for the press.

Dr. Pettit was a fellow of the American Association for the Advancement of Science, a charter member of the Entomological Society of America, a life member of the Society Linéene de Lyon, France, a member of the American Association of Economic Entomologists and of the Entomological Society of Washington The honorary degree of Doctor of Science was conferred on him by Michigan State College in 1931.

In 1895 Dr. Pettit was married to Jessa A. Treat of Ithaca, New York, who, survives him together with their two daughters, Mrs. M. S. Nelson of Indianapolis, Indiana, and Mrs. M. J. Reed of East Lansing, Michigan.—E. I. McDANIEL.

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS TO HOLD ANNUAL MEETINGS IN PITTSBURGH, DECEMBER 9 TO 12, 1946

The annual meeting of the American Association of Economic Entomologists will be held December 9 to 12 inclusive in the Hotel William Penn, Pittsburgh, Pennsylvania. The Hotel has set aside a generous number of rooms for those in attendance and early application for reservations should be made.

This will be a joint meeting with the Entomological Society of America. The Program Committee, acting for both societies, consists of A. M. Boyce, Chairman, G. J. Haeussler and C. E. Palm. The committee is integrating the schedule so that there will be several joint sessions and a maximum opportunity for the members of both societies to enjoy the contacts and the two programs.—E.N.C.

INTERNATIONAL GREAT PLAINS ENTOMOLOGISTS MEETING

The International Great Plains Conference of Entomologists (I. G. P. C. E.) was successfully revived following 6 years of voluntary suspension during the war period. On the invitation of the Dominion Entomological Laboratory, Lethbridge, Alberta, the meetings were held at Waterton Lakes, Alberta, July 24 to 26. Between 50 and 60 members and interested visitors attended the meetings.

Dr. C. E. Mickel, Chief of the Division of Entomology, University of Minnesota, was elected permanent chairman to fill the vacancy created by the retirement of Prof. A. G. Ruggles, Lt.-Col. C. B. Philip was appointed secretary for 1947.

The program included informal discussions on: The Insects of the Season, New Insecticides, Field Crop Insect Pests, The Present and Future Status of Entomology in the Area. In addition a joint session was held with the International Public Health officials, meeting simultaneously, on the subject, "Insects Affecting the Health of Man and Animals." The conference policy of informal discussion was reaffirmed.

Dr. Chas. N. Gould, recently retired head of the Oklahoma Geological Survey, was guest speaker at the banquet. His topic was "The Geology of the Great Plains."

The invitation of Dr. R. R. Parker to hold the 1947 meetings at the Public Health Laboratory, Hamilton, Montana, was unanimously accepted.

EASTERN BRANCH MEETING

The annual meeting of the Eastern Branch will be held on November 21 and 22 in Baltimore, Maryland with Headquarters at the Lord Baltimore Hotel.